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HAND-BOOK

TO

ASTRONOMY.

SHEET I.

The Solar System.

BY

THE REV. JAMES GALL.

W. & A. K. JOHNSTON,
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HAND-BOOK TO ASTRONOMY.

INTRODUCTION.

1. The world on which we dwell is a little star or planet, one of a family of eight, all travelling round the sun at different distances, and depending upon it for light and heat. They are also dependent upon it for guidance; for, were the sun taken away, the whole of the planets would wander from one another into the wide waste of heaven, being no longer held together in their places by the force of his attraction. The sun and planets are called the solar system.

2. The sun and moon appear to us as if they were nearly of the same size; but in reality it is not so. The sun is immensely larger than the moon; and the reason why the moon seems as large as the sun is, that it is very much nearer. A cannon ball travelling at the rate of a thousand miles an hour would reach the moon in ten days, whereas it would take more than ten years to reach the sun.

3. But the solar system itself is only a speck in creation, and the sun itself is only one among millions of stars. Far away in the heavens, and at immeasurable distances from one another, there are millions on millions of other suns and systems; but, because they are so far away, they appear only as stars, of which a few hundreds only are visible to the naked eye.

Figure I.

4. The paths in which the planets travel round the sun are like rings of different sizes, one within another; each outer one being nearly double the size of the one within. The planets therefore can never come near one another.

5. The earth, which is our planet, is the third from the sun, there being only two that are nearer. There are other five which travel in orbits outside, but astronomers are not certain whether there are not others still further away, which have not yet been discovered.

6. The position of the earth in the solar system is represented both in figures 1 and 2. No. 1 represents the earth and the two planets which are nearest to the sun. No. 2 represents the earth and the five planets which are furthest away. It will be observed that the scale of No. 2 is a great deal smaller than that of No. 1, because the orbit of Neptune (the most distant planet) is so great that the scale had to be very much reduced in order to take it in. In No. 1 the orbit of the earth is the largest; in No. 2 it is the smallest. The scale of both is so small that the sun cannot be represented in proportion; its place therefore is marked by a bright light in the centre.

We will now proceed to describe the several members of the solar system.

THE SUN (Fig. XL.)

7. The sun is the great centre of the solar system; and is so large, that if all the planets and comets that revolve around it were added to its bulk, it would not appear any larger than it does at present.

8. The diameter of the sun is upwards of 852,000 miles; that is to say, a line passing through the centre, and reaching from one side to the other, would be so many miles long. Supposing it possible to run a railway train round the sun at the rate of thirty miles an hour, it would take nine years to accomplish the journey.

9. So large is the sun in comparison with the earth, that, supposing the earth to be placed in the centre of the sun, there would be plenty of room inside for the moon to revolve around it; and even then there would be nearly as great a distance beyond, before reaching the surface of the sun. Diagram No. 31 shows the proportion of the orbit of the moon to the diameter of the sun.

10. When we examine the sun by means of a telescope, we find that the brightness diminishes from the centre, as represented in figure 40; the central portion being the brightest. The light of the sun proceeds from a sheet of flame, called the photosphere which floats in an atmosphere of unknown depth, and which is capable of absorbing its rays. As the photosphere rises and falls in waves, those portions which are highest are brightest, because there is less of the absorbing atmosphere above them; whereas those portions which are lowest are most obscured, in consequence of the rays having to pass through a greater depth of atmosphere. The brighter portions of the photosphere are called faculæ.

11. During a total eclipse of the sun we discover that the photosphere is not the only source of its light. As soon as it is covered by the moon's disc, rose-coloured flames are seen rising to a great height; and when closely examined, it is found that these flames are projected from a stratum of red light which encircles the sun, and that this stratum of red light is separated from the photosphere by a thin line of white light quite distinct from the photosphere, and not nearly so brilliant. This outer envelope is called the chromosphere.

Spots on the Sun.

12. At the equator, the sun's photosphere revolves on its axis in rather less than 31 days. In higher latitudes it revolves in rather more than 28 days. What the motion of the sun itself may be we cannot tell. This rotation has been ascertained by means of spots which break out on the sun's disc, and are seen to move across, appearing first on the left, and disappearing at the right side: see figure 40.

13. These spots appear first as small dim specks, which

sometimes grow to be great blotches of irregular forms, as shown in figures 40, 41, 42, 44. Sometimes they are so large as to be seen by the naked eye; but they must be looked at through a smoked glass to protect the eyes. They break out most frequently in the regions north and south of the equator, as represented in diagram 43; seldom on the equator itself, and never near the poles.

14. Although there is no regularity either in their shape or the time of their appearance, yet it has been ascertained that these spots have a period of eleven years, during which their numbers increase and diminish. For five and a half years they gradually increase till they attain a maximum, and during the next five and a half years they gradually decrease till they reach the minimum.*

15. A remarkable connection has also been observed between the spots on the sun and the aurora borealis. When the spots on the sun are greatest the aurora is most brilliant, and *vice versa*. The magnetism of the earth also is somehow connected with the disturbances on the sun's disc.

16. These spots are produced by openings in the photosphere in localities where violent changes are going on, during which there is a downward rush of the cooler atmosphere into the depths below, or an upward rush of glowing hydrogen into the chromosphere above.

17. In the spots there are different shades of darkness. There is first the outer part called the *penumbra*, which is not nearly so bright as the photosphere. Within the *penumbra* there is a still darker portion called the *umbra*, and in the centre there is the *nucleus*, which, though not black, has the appearance of being so.

18. A minute examination of the photosphere shows that it is composed of separate masses of bright tongues of fire crowded together at different depths; the interstices between them appearing as 'pores' or 'punctuations;' but at the

* Mr Carrington has detected 'a great contraction of the limiting parallels between which spots are found previously to the minimum . . . . and soon after this epoch, the apparent commencement of two fresh belts of spots in high latitudes north and south, which have in the subsequent years shown a tendency to coalesce and ultimately to contract as before, to extinction.'

edges of the spots, where they are in rapid motion, they have the appearance of 'straws,' 'willow leaves,' and 'rice-grains' pointing towards the interior of the spot, like the thatching of a roof. It has also been observed that they are not permanent objects, but gradually melt away as if they were flames.

19. The size of the sun-spots is very varied. They are sometimes very small, sometimes very large—so very large that our world might be dropped through the nucleus, without coming within a thousand miles of the umbra.

20. These spots give evidence of commotions in the sun's atmosphere so violent as to be beyond all conception. They appear and disappear, and change their shapes, with marvellous rapidity.

21. The heat which is given out by the sun is so great, that no heat which we can produce artificially is to be compared to it. It has been calculated that from every square yard of the sun's surface, the amount of heat sent forth is equal to what a blast furnace would produce, burning a ton of coals every ten minutes.

22. The light of the sun also is far greater than any artificial light which we can produce by combustion. The lime-ball light, which is one of the most brilliant that we know, is dark compared with the sun. When held in front of the sun's disc the lime ball appears as a black spot.

23. Besides the outer envelopes which lie upon the photosphere, there appears to be an extensive atmosphere surrounding the sun, which can be seen only during a total eclipse. When the sun, itself is hidden, it shines with a silvery light all around, and is called the CORONA. There are also protuberances and fancifully shaped flames projected from the sun's surface, which also appear during a total eclipse. These will be exhibited in another sheet.

THE PLANETS.

Mercury (Fig. XV.)

24. We now proceed to notice, in their order, the planets which revolve round the sun, the nearest of which is Mercury,

travelling in the orbit shown in fig. 1, at a distance of more than 35,000,000 of miles.

25. Mercury is so near the sun that it can seldom be seen distinctly; yet astronomers have been able to discover that it revolves on its axis in about twenty-four hours, so that its day is nearly the same as ours; but as it travels round the sun in less than three months, its year is only a quarter of our own.*

26. It is remarkable that Mercury, although it is the smallest, is also, in proportion, the heaviest of all the planets. Its specific gravity is supposed to be more than ten times greater than that of Saturn, and as six to five compared with the density of our own world.

Venus (Figs. VIII., XIV. XXI.)

27. Next in order is the planet Venus, which is the nearest to our earth both in size and position, and is by far the brightest star in the heavens. Being much nearer to the sun than we are, it is never sufficiently far from the sun to enable us to see it, except in the mornings and the evenings. For that reason it is called both the morning and the evening star. It is nearly the same size as the earth, being only a little smaller; its specific gravity also is nearly the same, being only a little less; but its seasons are very different, on account of its poles being much more sloped than ours. See fig. 21.

28. Venus travels in her orbit at a distance from the sun of more than 66,000,000 of miles, and performs her journey round it in seven months and a half. Her day is very nearly the same length as our own, as she revolves on her axis in about twenty-three hours and a quarter.†

29. Mercury and Venus are the only planets that can come between the earth and the sun. When they do pass, they appear as little black beads moving across its disc. It is by observing these transits from different parts of the earth's sur-

* The sun appears very much larger when seen from Mercury, than when seen from the earth, see figure 30.

† The sun appears considerably larger when seen from Venus, than when seen from the earth. See fig. 30.

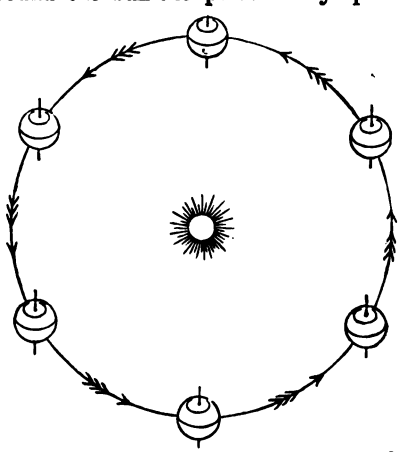
face, and measuring the difference, that astronomers have been able to discover the distance of the earth from the sun.

The Earth (Figs. XVI., XXII.)

30. Our own world is the third planet from the sun, and moves in its orbit at a distance of more than 91,000,000 of miles. It accomplishes its journey in rather more than 365 days six hours, and thus completes its year. As we count only 365 days in the year, the six hours additional accumulate to a whole day every four years. This is added to the 28th of February, and makes what is called LEAP YEAR.

31. The earth also turns on its axis every twenty-four hours, which is our day; but as the axis is oblique, the north pole being bent down 23½ degrees, and the south pole lifted up to the same extent, a variety of seasons is produced during its passage round the sun.

32. In travelling round the sun the poles always point in the same direction, so that at one part of the year the north pole points forward; but as it turns in the circle it gradually goes sideways, till coming round again on the opposite side, the south pole takes the lead. This is the cause of the change of seasons in each hemisphere. When the northern hemisphere points away from the sun, it is the northern winter and the southern summer; but when it points towards the sun, it is the northern summer and the southern winter.



33. Our planet is covered with what might be called a film of water, which we call the ocean, and which is probably

on an average not much more than two miles deep. If represented on a common globe, it would not be deeper than the varnish on the outside.

34. The earth is also surrounded by a dense envelope of air, which adheres to it, and is called its atmosphere. This atmosphere, which is somewhere between fifty and eighty miles in height, is necessary for the existence of plants and animals; but it is only at the very bottom that it is dense enough for this purpose. As it ascends it becomes thinner and thinner, until it disappears altogether. The layer at the bottom, in which alone plants and animals can live, is only a few miles deep, so that if it were represented on a common globe, it would not be much thicker than another heavy coat of varnish.

35. The mean density of the earth is five and a half times greater than water—that is to say, it is heavier than stone, but not so heavy as iron.

The Moon (Fig. XXXII.)

36. Our world is attended by a satellite or moon, which travels round it at a distance of 238,000 miles, see fig. 3. It is much smaller than the earth, being only 2,153 miles in diameter, and yet it is nearly as large as the planet Mercury. Fig. 19 gives an idea of its size compared with the British isles.

37. The moon travels round the earth once in twenty-seven days and seven hours, during which time it gradually changes its appearance. From 'new moon' (when it is invisible) it changes to a thin crescent, see fig. 33, and 'half moon,' see fig. 34. From that time it gradually increases till the whole face or disc is illuminated, which is called the 'full moon.' Gradually it wanes to the third quarter, and from that dies away to new moon again.

38. The density of the moon is rather more than one-half of that of the earth; and as there does not appear to be any water on its surface, or any atmosphere surrounding it, it has been suggested that when the outer crust was formed and became rigid at a very high temperature, interior vacancies may

have been formed by the subsequent cooling of the mass and shrinking in bulk, and that into these the sea and the atmosphere may have retired. In diagram No. 23 the outer circle of white represents the difference between the *apparent* specific gravity of the moon, and the specific gravity of the earth. It would also represent the extent of the vacancy between the outer crust and the inner nucleus, supposing their *real* specific gravity to be the same.

39. The mountains of the moon are very peculiar, see figs. 35, 36, being chiefly circular, and of the most varied dimensions. They resemble the ring-shaped elevations produced by droppings falling into liquid plaster, the smaller ones having the appearance of rain drops, but of gigantic size. There are also level plains lower than the mountain country, the dark colour of which suggests that they were formerly covered with water. The height of the mountains of the moon is proportionally greater than the height of the mountains on the earth.

40. As the moon always keeps the same side turned towards the earth as she journeys round, we are never able to see the other side. Her day is the same length as her year, because she turns on her axis in exactly the same time that she revolves in her orbit.

41. The plane of the moon's orbit round the earth is not the same as that of the earth round the sun. One half is higher than the ecliptic, the other is lower; it must therefore cross the sun's path twice every month at the two points, which are called the nodes. If the sun happens to be at one of these nodes when the moon is passing across, an eclipse of the sun takes place—that is to say, the moon comes between us and the sun. If only a part of the sun is covered, it is called a *partial eclipse;* if the whole is covered it is called a *total eclipse;* but it sometimes happens that the moon crosses when the sun is nearer to us than usual and the moon further away; in that case an *annular eclipse* takes place, which means, that the moon, not being large enough to cover the whole sun, leaves the outer edge uncovered, which shines like a luminous ring.

42. When the sun happens to be at one node and the moon at the other, an *eclipse of the moon* takes place; so that instead of the moon casting its shadow on the earth, the earth casts its

shadow on the moon, and as the earth's shadow is very much larger than the moon's, the eclipses of the moon are much more frequent than the eclipses of the sun.

Mars (Figs. XVII., XXIV., XXIX.)

43. We now call attention to the second diagram, in which the orbits of the earth and the superior planets, are represented. The planet nearest to the earth on the outside is MARS. Like Mercury and Venus, it is a solitary world, having no moon to cheer the darkness of its night. It is comparatively a small planet, being only 4,920 miles in diameter, and turns on its axis in a little more than 24½ hours. Its day therefore is slightly longer than our own.*

44. Mars moves in an orbit upwards of 139,000,000 of miles distant from the sun, and takes a year and nearly eleven months to complete its journey. The axis on which this planet turns is oblique, so that each hemisphere has a summer and winter in turn. It has also an atmosphere of some kind, which though not so dense as our own, prevents us from seeing very clearly its geographical features, see fig. 24.

45. So far as can be made out, the greater part of the surface is land, only a small portion being water. There must also be water in the atmosphere which descends in the form of snow; as we can see at either pole a white patch, which becomes larger in winter and smaller in summer. In figure 29 will be found the geographical features of Mars, so far as they have been ascertained by means of powerful telescopes, with the names of the continents and seas by which they may be referred to.

* The sun, when seen from Mars, appears considerably smaller than when seen from the earth, see fig. 30.

The Asteroids, or Minor Planets (Fig. II.)

46. There is considerable regularity in the increasing distances of the planets from the sun; each planet being more than a half further away than the one nearer. But between Mars and Jupiter there is double the usual distance, as if a planet ought to have been there which is awanting. There is, however, in place of a single planet, a perfect shoal of miniature ones, all moving in one broad path, yet never coming into collision one with another. Although upwards of a hundred have been discovered and named, it is probable that there are hundreds more, some of them not larger than one of our own mountains. To distinguish them from the other members of the solar system, they have been called asteroids, planetoids, and minor planets.

Jupiter (Fig. XII., XXV.)

47. Beyond these fragmentary bodies, we find the planet Jupiter, the largest of the whole family, and the second brightest star in our heavens. It is upwards of 85,000 miles in diameter, so that it is more than a thousand times larger than our own world. There is reason to believe, however, that what we see is not the planet itself, but only the outside of its atmosphere; and as there are evidently great commotions taking place within, the depth of the atmosphere must be very great. This is the more probable, as the density of the planet is so very small that it would almost float in water (see fig. 25). As there is no reason to suppose that the planet itself is composed of materials lighter than those of our own earth, it is more than probable that the solid nucleus is less than half of that which is visible. If the planet be not yet cooled, and if its future ocean be still in the form of steam, we have an easy explanation of its enormous bulk, and the violent commotions which are taking place within.*

* The brilliant white of its equatorial regions has led some to suppose that Jupiter shines partly by a light of his own. It is more probable that it is caused by the aqueous vapour ascending in huge masses from beneath, and turning into snow as it travels along before descending into the interior to be re-melted and heated for another ascent.

48. The orbit of Jupiter is upwards of 475,000,000 of miles distant from the sun, and it takes nearly twelve years to make a complete revolution, travelling at the rate of 30,000 miles an hour. Jupiter turns on its own axis in less than ten hours, so that its day is less than one-half of ours. This great velocity of rotation bulges out the sides and flattens the poles of this planet, so that in the telescope it appears far from being round. Its measurement from pole to pole is more than 6000 miles less than at the equator.*

49. The body of Jupiter is crossed by a number of shaded bands or belts, not of any regular form, and not always the same. The largest and most permanent bands are near the equator on both sides; the equator itself is in general more luminous than any other part of the disc. Outside of these larger belts, towards the poles, the smaller bands are continually changing.

50. There are four moons which revolve round Jupiter at different distances, like planets round the sun, as shown in fig. 6. The second is nearly the same size as our own moon, the first and fourth are larger, and the third is the largest of all.

51. These moons of Jupiter undergo eclipses much more frequently than our own moon, having to pass so frequently under the shadow of the great planet. There are also eclipses of the sun on Jupiter, but the moons are so small that their shadow appears only as a little black spot travelling across its surface.

Saturn (Figs. IX., XVIII., XXVI.)

52. Next to Jupiter is the planet Saturn, which, though not quite so large, is even more wonderful. It is the sixth in the order of distance from the sun (not counting the asteroids), and the third which travels outside of the earth's orbit. Its diameter is nearly 72,000 miles, its distance from the sun upwards of 872,000,000 miles, and it takes nearly twenty-nine years and a half in completing its journey round the sun. Saturn turns on its axis, which is much more oblique than that of Jupiter, in ten hours and a half, see fig. 26.

* The sun, as seen from Jupiter, appears much smaller than when seen from the earth, see fig. 30.

53. To the naked eye Saturn does not appear very bright; he is fainter than Venus, Jupiter, or even Mars, and his colour has a dull yellowish appearance, which made the ancient astronomers speak of him as having a very gloomy influence on mankind. This was the last of the planets known to the ancients, who attributed to each of them some peculiarity. Those born under the influence of Mercury, the Moon, Mars, Jupiter, or Saturn, were called *mercurial* or sprightly, *lunatic* or insane, *martial* or warlike, *jovial* or merry, *saturnine* or grave.*

54. When looked at through the telescope, Saturn is a most interesting and beautiful object, because, besides being attended by eight moons, he is encircled with a splendid system of thin but broad rings, unlike any other star in the heavens.

55. In fig. 18 Saturn will be easily distinguished from all the other planets by his rings, which we will now describe. There are really three distinct rings, and even these may be divided into smaller ones. The outer ring, which of course is the largest, is nearly 167,000 miles in diameter, and nearly 10,000 miles broad. The central ring is 144,000 miles in diameter, and nearly 18,000 miles broad; but the most remarkable is the inner ring, which is almost transparent, and which stretches, like a thin gauze frill, from the central ring to within 10,000 miles of the planet.

56. What these rings are composed of is at present unknown; the most probable conjecture is, that they are made up of an immense amount of loose materials, revolving in different orbits, probably meteoric stones, at considerable distances from one another. The changes which are continually taking place in the appearance of the rings appear to favour this supposition.

57. The rings do not always present the same front to this earth. At one time they are in the plane of the earth's orbit, so that only the edge is presented to us, as in figure 9. They then begin to turn their side to us, as in figure 18; after

* The sun, as seen from Saturn, is very much smaller than when seen from the earth, see fig. 30.

which they again contract, and show the thin edge as before; and lastly, they turn their other side to us, and again presenting the thin edge, having completed their oscillation. These changes are caused by the planet's equator being inclined at a considerable angle from the plane of the earth's orbit.

58. Saturn has his poles flattened like the planet Jupiter, in consequence of his rapid rotation on his axis; and, like Jupiter, is girdled with belts, which, however, are not so distinctly marked. As is the case with Jupiter, the equatorial regions are the brightest.

59. The apparent density of Saturn is the least of all the planets, and does not exceed that of hard wood. As in the case of Jupiter, there is no necessity for supposing that it is made of very light materials; because, as we see only the outside of its atmosphere, the globe itself may be comparatively small. What we have said of the atmosphere of Jupiter may also be said of the atmosphere of Saturn. See fig. 26.

60. The satellites of Saturn are eight in number, and revolve in orbits as represented in fig. 7.

Uranus (Figs. XI., XXVII.)

61. Uranus, which was discovered by Sir William Herschell in 1781, was unknown to the ancient astronomers. It moves in an orbit nearly 1,754,000,000 of miles distant from the sun, and accomplishes its journey in rather more than eighty-four years. It turns on its own axis, but not in the same direction as the earth, see fig. 27. His diameter is 33,000 miles, so that although much larger than the earth, it is not nearly so large as Jupiter, or even Saturn.*

62. The density of Uranus is greater than that of Saturn, but not so great as that of Jupiter. It is probable, therefore, that it also is surrounded with a great atmosphere, which makes it appear double its real size. No spots or bands have yet been discovered to enable us to measure the length of its day. This is not to be wondered at, considering how great the

* The sun appears only as a dazzling star of extraordinary magnitude, see fig. 30.

distance is between it and us, and the feeble light it receives from the sun, see Fig. 30.

63. Uranus has four moons, see fig. 5; but it is remarkable that they revolve backwards, that is to say, in a direction opposite to that which the moons of Saturn and Jupiter follow. There may be other moons besides the four, but their great distance prevents them from being seen from the earth.

Neptune (Figs. XIII., XXVIII.)

64. After the discovery of Uranus, astronomers were puzzled by the irregularity of its motion at one part of its journey round the sun. This could only be accounted for by supposing that another planet was revolving outside, so that when the one passed the other, the outer planet disturbed the motion of the one within. This led two of our most distinguished astronomers, Adams and Leverrièr, one in England and the other in France, to make calculations in order to discover the place where this exterior planet might be found. Adams was the first to point out the place; but for want of star maps sufficiently minute to discover the stranger, the astronomers of England failed to recognize it. Leverrièr having also completed his calculation, wrote to Dr Galle in Berlin, who, by means of the star maps in his possession, recognized the new star in the place mentioned by Leverrièr, as one that had not been there before. The new planet was called Neptune.

65. Neptune is distant from the sun 2,746,000,000 of miles, and performs his journey round it in rather less than 165 years. The diameter of Neptune is nearly 37,000 miles, and its density rather less than that of Uranus, see fig. 28.

66. One moon has already been discovered revolving round Neptune; probably there are more. Like those of Uranus, it is believed that its motion is retrograde. Its orbit is shown in fig. 4.

COMETS (Figs. XXXVII., XXXVIII., XXXIX.)

67. Our description of the solar system would not be complete without some account of the comets, which form an

entirely different class of bodies, both in regard to their movements and their constitution. Their name is derived from the Latin 'Coma,' which means HAIR, and they are so called on account of their tails, which stream out behind them like the tail of a horse.

68. The brightest part of the comet is the head, which, in some cases, contains a still brighter patch, called the nucleus. No part of the comet is so dense as the air we breathe, and stars can be seen through any part of its body. As comets do frequently cross the orbit of the earth, it was once feared that the earth might be destroyed by their coming into collision. There is reason to believe, however, that the earth may have occasionally passed through comets without the inhabitants being at all aware of it. So unsubstantial are they, that although they are easily turned out of their path by coming near a planet, they have not the slightest influence on the movement of the planets themselves or even of their moons.

69. All the planets move, more or less, in one plane, whereas the comets move in all directions. The planets move in orbits that are nearly circular, whereas the comets move in elliptical orbits that are very much elongated. Some comets have their orbits within that of Neptune, and perform their journey in a few years; others come from, and go back to, distances of unknown extent, so that it is doubtful whether they shall ever return. The orbits of a number of comets are shown in fig. 37.

70. The motion of a comet always increases as it approaches the sun, and diminishes as it goes away. In whatever position the comet may be, whether in going or coming, the tail is always pointed away from the sun.

DESCRIPTION OF THE DIAGRAMS.

FIGURE I. Represents the earth and the INTERIOR PLANETS,*

* In astronomical works Mercury and Venus are called the INFERIOR PLANETS, and those beyond the earth, the SUPERIOR PLANETS, because the sun, being the great centre of attraction, and all the planets being inclined to fall down into it, those that have the least distance to fall are called lowest, and those that have the greatest distance to fall are called the highest.

Mercury and Venus. Instead of looking down on their orbits from above, as generally represented, we see them in prospective, that is, sideways.

FIGURE II. Represents the earth and the EXTERIOR PLANETS, that is, those that are further away from the sun.

FIGURE III. Represents the orbit of our own moon.

FIGURE IV. Represents the orbit of the moon of Neptune.

FIGURE V. Represents the orbits of the four moons of Uranus.

FIGURE VI. Represents the orbits of the four moons of Jupiter.

FIGURE VII. Represents the orbits of the eight moons of Saturn.

FIGURE VIII. Represents Venus as she appears in the telescope, first as a thin crescent, then as a half moon. We never can see the full face of Venus, because she is nearer to the sun than we are. It will be observed that besides the half of the planet which is enlightened by the sun, there is an additional portion in twilight; proving that there is an atmosphere of considerable extent like that of our own world.

FIGURE IX. Represents Saturn at the time when his rings are in the plane of the earth's orbit, so that we see only their edges. Near the planet the rings appear nebulous. It is supposed that this is caused by the materials of which the rings are composed revolving in orbits of different inclinations. At the extremity the rings are so thin that they do not appear continuous.

FIGURES XI. to XVIII. Represent the appearance and comparative size of the planets. The segment of a circle at the foot represents, in the same proportions, a part of the sun, which would be four feet in diameter.

Supposing then the sun to be four feet in diameter, MERCURY would be of the size represented in the figure, and would revolve, at the distance of 55 yards, at the rate of 10 feet 8 inches a day.

VENUS would revolve at the distance of 103 yards, at the rate of 8 feet 7 inches a day.

The EARTH would revolve at the distance of 142 yards, at the rate of 7 feet 4 inches a day.

MARS would revolve at the distance of 219 yards, at the rate of 6 feet a day.

JUPITER would revolve at the distance of 744 yards, or nearly half-a-mile, at the rate of 3 feet 3 inches a day.

SATURN would revolve at the distance of 1362 yards, or three-quarters of a mile, at the rate of 2 feet 6 inches a day.

URANUS would revolve at the distance of 2740 yards, or a mile and a half, at the rate of 1 foot 8 inches a day.

NEPTUNE would revolve at the distance of 4290 yards, or about two miles and a half, at the rate of 1 foot 4 inches a day.

FIGURE XIX. represents the size of the moon as compared with the British isles.

FIGURES XX. to XXVIII. Represents the specific gravity or comparative density of the various members of the solar system, and the inclination of the axis of each, without reference to size. The interior nucleus is the real body of the planet (or sun) supposing it to be of the same density as the earth. Of course we cannot tell whether they are composed of the same or similar materials or no; but there is no reason to suppose that they are greatly different. Mercury is not represented because his density is even greater than the earth, and the inclination of his axis is not certainly known. In the case of all the others, except the moon, what we see is the limit of their atmospheres, not the planets themselves: we may therefore account for their extreme lightness, by supposing that all beyond the nucleus is atmosphere. In the case of the moon it is not so. If there be any atmosphere it must be in the interior. See section 39.

FIGURES XXIX. Represents the geographical features of Mars in four orthographic views. The names given to the continents and seas are those of eminent astronomers.

FIGURE XXX. Represents the apparent magnitude of the sun as seen from the different planets.

FIGURE XXXI. Represents the size of the sun as compared with the orbit of the moon.

FIGURE XXXII. is a telescopic view of the moon drawn from numerous photographs. See section 40.

FIGURE XXXIII. The moon as a thin crescent, four days old.

FIGURE XXXIV. The moon when a little more than half full.

FIGURE XXXV. Copernicus, a mountain in the moon, towards the left side, and near the centre of the limb.

FIGURE XXXVI. Mountain formations near Tycho, the radiating mountain in the South. For these two drawings we are indebted to the kindness of James Nasmyth, Esq.

FIGURE XXXVII. Represents the orbits of a number of comets connected with the solar system.

FIGURES XXXVII., XXXVIII., and XXXIX. Comets. See section 68.

FIGURE XL. Is a telescopic view of the sun, as described at pages 4, &c.

FIGURES XLI., XLII., and XLIV. Telescopic views of the spots on the sun. See section 12.

FIGURE XLIII. A diagram showing the regions on each side of the sun's equator in which the spots generally break out. See section 14.

TABLES.

No. I.—Signs of the Solar System.

Mercury,	☿	Saturn,	♄
Venus,	♀	Uranus,	♅
Earth,	♁ or ⊕	Neptune,	♆
Mars,	♂	The Sun,	☉
Jupiter,	♃	The Moon,	☾

No. II.—Signs of Degrees.

Degrees ° Minutes ′ Seconds ″

Diameter of the Members of the Solar System.

Mercury, . .	2,962 miles.	Saturn, . .	71,904 miles.
Venus, . . .	7,510 ,,	Uranus, . .	33,024 ,,
Earth, . . .	7,901 ,,	Neptune, . .	36,620 ,,
Mars, . . .	4,920 ,,	Sun, . . .	852,584 ,,
Jupiter, . . .	85,390 ,,	Moon, . . .	2,153 ,,

Their Distances from the Sun.

Mercury,	35,393,000 miles.	Jupiter,	475,693,000 miles.
Venus, .	66,131,000 ,,	Saturn,	872,135,000 ,,
Earth, . .	91,430,000 ,,	Uranus,	1,753,851,000 ,,
Mars, .	139,312,000 ,,	Neptune,	2,746,271,000 ,,

Moon distant from the earth, 238,793 miles.

Periods of Revolution in their Orbits.

	D.	H.	M.		D.	H.	M.
Mercury, .	87	23	15	Jupiter, .	4,332	14	2
Venus, . .	224	16	48	Saturn, .	10,759	5	16
Earth, . .	365	6	9	Uranus,	30,686	17	21
Mars, . .	686	23	31	Neptune,	60,126	0	0

The moon, 27 days 7 hours 43 minutes.

Period of Rotations on their Axes.

	H.	M.	S.		H.	M.	S.
Mercury, . .	24	5	28	Jupiter, . .	9	55	28
Venus, . . .	23	16	19	Saturn, . . .	10	29	17
Earth, . . .	23	56	4	Uranus, . .	unknown.		
Mars, . . .	24	37	23	Neptune, . .	unknown.		

Sun, 29 days.

Inclination of Euqator to Orbit.

Mercury, . .	unknown.	Jupiter, . . .	3° 4′
Venus, . . .	49° 58′	Saturn, . . .	26° 49′
Earth, . . .	23° 27′ 24″	Uranus, . . .	100° 20′
Mars, . . .	28° 51	Neptune, . .	unknown.

DENSITY OF EARTH AS 1.

Mercury,	1·24	Saturn,	0·12
Venus,	0·92	Uranus,	0·18
Earth,	1·	Neptune,	0·17
Mars,	0·92	Sun,	0·25
Jupiter,	0·22	Moon,	0·566

Density of earth, $5\frac{1}{2}$ times that of water.

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No. II.—ASTRONOMICAL DIAGRAMS.

I. THE EARTH AND THE HEAVENS.

1. In olden times it was supposed that the earth was an immense plain, surrounded by an ocean, extending no one knew how far; and that the sun, moon, and stars, were in motion round the world, no one knew how. It is now certain that this was a great mistake; and that the earth, instead of being a plain, is a large globe, which revolves on its own axis; so that it is not the heavens that are in motion: it is the earth that moves.

2. The same illusion is produced when we are travelling by rail. The trees and houses seem to rush past, while the carriage, in which we are seated, appears to be standing still. Of course we know that it is the carriage that is in motion, and not the country.

3. The ancients supposed that the earth was the centre of the universe; and the sun, moon, and stars seemed so small in comparison, that they never supposed but that the earth was immoveable; when, however, astronomers discovered that the sun was more than a thousand times larger than the earth, and that the stars were millions of millions of miles distant, they concluded that it must be the earth revolving on its own axis that made the heavens appear to revolve.

4. There are many proofs that the world is a globe, and not

a plain; but there are three which any one may understand—1st, Ships have often sailed round the world, arriving at the place from which they set out, without having to turn back. 2d, We can see the shadow of the earth upon the moon when the moon is eclipsed, and that shadow is always round. 3d, If the world were a flat surface and not a globe, the sea also would be a plain; and, however far a ship might sail away, although it would always be becoming smaller in appearance, it never could go out of sight. Instead of this being the case, however, we can see the sea to be actually round, and the ships disappearing on the other side. We first lose sight of the hull, then the sails, and at last the top of the mast disappears, as illustrated in Diagram No. 1.

5. When we look up into the heavens we see continual changes going on. In the morning the sun, after rising in the east, glides upward till he reaches the middle of his course, which is due south, and then he glides downward till he disappears below the horizon in the west.

6. When the sun has set, an entirely new scene begins to open to our view. At first only a few stars present themselves in the evening sky; but, as the twilight fades, one after another discovers itself to our notice, till the whole sky is spangled with their multitude. To the unaccustomed eye the stars appear as if they were all at rest; but if we continue our observations from hour to hour, we discover that, like the sun, they are continually in motion,—rising in the east and setting in the west.

7. Figure 2 represents the earth in motion on its own axis, causing alternately day and night. One half of the earth, being exposed to the sun, is in the light of day, the other half, which is turned away from the sun, is in the darkness of night. Between the two there is a shaded stripe all round, which represents the twilight, produced by the sun shining on the atmosphere over those parts where it has not yet begun to shine upon the earth itself.

8. The arrow shows the direction in which the earth revolves, being from west to east; so that the sun is just about to rise to the parts which are in twilight. As they turn round, the sun appears to ascend in the heavens, till it is in the full

blaze of noon. When they have reached the other side, the sun will appear to set; and, through the twilight, they will pass into the darkness of night.

9. In the evening, the whole firmament is seen as a hollow sphere, revolving on an axis in the heavens, corresponding with the axis of the earth. One half of the heavens, therefore, must be above the horizon, and the other half below.

10. After observing the heavens for a few weeks or a few months, we discover that the sun is travelling among the stars in a path of his own.

11. As the apparent revolution of the heavens round the earth is caused by the rotation of the earth on its own axis, so the apparent course of the sun among the stars, performing its journey in a circle once a year, is caused, not by the motion of the sun in an orbit round the earth, but by the motion of the earth in its orbit round the sun.

12. Astronomers have divided the path of the sun round the heavens into twelve parts or stages, called the signs of the Zodiac, each having an imaginary figure drawn in the sky. They are as follows. (*See Figure* 29).

SIGNS OF THE ZODIAC.

♈ Aries (*the Ram*)	♎ Libra (*the Scales*)
♉ Taurus (*the Bull*)	♏ Scorpio (*the Scorpion*)
♊ Gemini (*the Twins*)	♐ Sagittarius (*the Archer*)
♋ Cancer (*the Crab*)	♑ Capricornus (*the Goat*)
♌ Leo (*the Lion*)	♒ Aquarius (*the Water bearer*)
♍ Virgo (*the Virgin*)	♓ Pisces (*the Fishes*)

The scholar may help his memory by learning the following lines—

The Ram, the Bull, the heavenly Twins;
And next the Crab, the Lion shines,
The Virgin, and the Scales,
The Scorpion, Archer, and Fish-goat,
The Man that pours the water out,
And Fish with glittering tails.

13. Diagram No. 5 is a landscape illustration of the orbit of the earth round the sun, with the signs of the Zodiac in which he appears to travel. The surface of the pond represents the ecliptic or the plane of the earth's orbit; the large ball in the

centre represents the sun, and the little ball travelling round it represents the earth. As neither the sun nor the earth have their poles perpendicular, their equators do not coincide with the surface of the lake; one half being above, and the other half below the water. The two points at which the equator cuts the surface are called the equinoctials, because, when they face the sun, the days and the nights are equal. (*See Diagram* No. 15.) The earth in moving round the sun, keeps the poles always pointed in the same direction: so that in summer the north points towards the sun, and in the winter it points away from the sun. When a spectator, supposed to be on the earth, looks towards the sun in the landscape, he sees part of the shore in the same line with the sign of the Zodiac in which he happens to be. In like manner, as the earth moves in its orbit, the sun appears to travel through the signs. From the position which the earth occupies in the diagram, the sun appears to be in the sign Capricornus.

II. DOCTRINE OF THE SPHERE.

14. The study of astronomy requires that we should be able to refer to any point in the whole heavens with the utmost exactness; and for this purpose astronomers have adopted a very simple method, as shown in Figure 3, by means of two circles crossing one another at right angles.

15. They first imagine one great circle cutting the sphere perpendicularly into two equal parts; and then they imagine another great circle cutting the sphere horizontally into two equal parts. The perpendicular circle, which measures the latitudes, is first divided into two equal parts by the zenith above and the nadir below, and again into four equal parts by the horizontal circle which divides the north from the south. (The zenith is the central point of the upper hemisphere, the nadir is the central point of the lower hemisphere.)

16. Each of these circles is divisible into four quadrants and each quadrant is divided into ninety equal parts, called *degrees*; each degree is further divided into sixty minutes;

and each minute is sub-divided into sixty seconds. The degrees are marked thus (°), the minutes thus (′), and the seconds thus (″); so that 30°, 30′, and 30″, would mean 30 degrees, 30 minutes, and 30 seconds. By this means the circle is divided into more than a million of parts. This is sufficiently minute for all ordinary purposes.

17. In applying these measurements to the heavens, we first mark the *height* of any point or star by its distance from the north pole, and this is called its North Polar Distance. What is called the Declination of a star is its distance (north or south) from the equator. The measurement of the longitude is not so easy, because the horizontal circle has no pole from which we can count; but astronomers have agreed to reckon the longitude of any star by its distance from the spring equinox, which is that point in the heavens where the sign of Aries begins. This is called the Right Ascension of the star, and is measured by hours, minutes, and seconds, the whole circle measuring twenty-four hours.

18. The Equator is the great circle which divides the sphere into two equal halves, the northern and the southern hemispheres: but, as the earth does not revolve in its orbit in an upright position, but with its poles inclined 23½ degrees, as seen in Diagram No. 4, the plane of the earth's orbit does not coincide with the equator, but is 23½° higher at one part of the year, and 23½° lower at another. The plane of the earth's orbit is called the ECLIPTIC, cutting the earth's equator at two points, called the VERNAL (spring) EQUINOX, and the AUTUMNAL EQUINOX. When the sun crosses these points the days and nights are equal. (*See Diagram* No. 15.)

19. The Equator and the Ecliptic, being natural circles, are of great importance, because they provide the natural divisions

of the sphere. (*See Diagram* No. 4.) If two minor circles be drawn through the poles of the Ecliptic parallel to the Equator, we have the Arctic and Antarctic Circles. A minor circle touching the *highest* point of the Ecliptic, and parallel to the Equator, gives us the Tropic of Cancer; and another minor circle touching the *lowest* point of the Ecliptic, and also parallel to the Equator, gives us the Tropic of Capricorn.

20. These four minor circles divide the world into five naturally different regions—(1st), Within the arctic and antarctic circles are the arctic and antarctic regions, where the sun does not rise at mid-winter, nor set at mid-summer; (2d), Between the tropic of Cancer in the northern hemisphere, and the tropic of Capricorn in the south, are the tropical regions, in every part of which the sun shines directly overhead at some part of the year; and (3d), Between the tropical regions, and the arctic and antarctic regions, are the temperate regions, where the sun rises and sets every day, but never shines directly overhead.

III. CLIMATES.

21. The climate of any country depends on the place which it occupies between the equator and the poles. The nearer it is to the poles, the colder is the climate: the nearer it is to the equator, it is the warmer. Diagram No. 6 represents the path of the sun as seen at the poles, it being above the horizon one half of the year, and below the horizon the other half. In March the sun begins to appear above the horizon, travelling slowly round it every day, the upper half alone being visible; but, as it travels round the horizon day by day, it gradually rises until the whole disc appears. On the 21st of June it has reached its highest elevation, and begins again to descend in daily circles till it reaches the horizon; and at length disappears, leaving the poles in darkness for nearly half a year.

22. Diagram No. 7 represents the sun's path as seen at the equator, which has two summers and two winters every year. Instead of turning in circles parallel to the horizon, as at the

poles, the sun travels perpendicularly right up into the sky from the east, and right down again on the other side to the west. The first summer is in March, when the sun is directly overhead at 12 o'clock. It gradually declines to the north till June, which is its first winter, and then returns to its central position in September, which is its second summer. It continues to go southwards till December, its second winter; and then returns northwards to complete its seasons. As the sun cannot descend more than $23\frac{1}{2}°$ from the zenith, the equatorial winters are nearly as hot as the summer in Britain: the summers of course are the hottest in the world.

23. Diagram No. 12 represents the climate of temperate regions, as experienced at London, which is $51\frac{1}{2}°$ north of the equator. The sun travels here, not horizontally as at the poles, nor perpendicularly as at the equator, but obliquely, rising from the east towards the south, and descending obliquely to the west. On the 21st June the sun is 75° above the horizon at mid-day: on the 21st December it is only 28°.

24. Diagram No. 13 represents the sun's path as seen in Australia, which is in the temperate regions of the southern hemisphere, where the seasons are reversed. The northern summer is the southern winter, and the northern winter is the southern summer. The 21st of December is the middle of summer, and the 21st of June is the middle of winter. The sun's path also during the day appears to be reversed: it rises, no doubt, in the east, and sets in the west; but, as it shines in a northern and not in a southern sky, it rises on the right and sets on the left, as if it went backwards.

IV. THE SEASONS.

25. Diagram No. 15 represents the succession of the seasons in the northern and southern hemispheres respectively, which are represented separate to show the difference more plainly. The earth is represented in its journey round the sun in four

different positions, illustrating the four seasons—summer, autumn, winter, and spring.

26. On the right side the position of the earth is represented as on the 21st June, which is the northern midsummer, and the southern midwinter. The northern hemisphere being turned towards the sun, has the greatest amount of sunshine, because, as the sun rises earlier and sets later, the days are longer. The southern hemisphere, on the contrary, is on that same day turned away from the sun, and has, therefore, the smallest amount of sunshine. The days are short and the nights are long, because the sun rises later and sets earlier.

27. On the upper side of the diagram the position of the earth is represented as on the 21st September, when the ecliptic crosses the equator, and when the days and nights are equal in both hemispheres.

28. On the left side of the diagram the position of the earth is represented as on the 21st December, which is the northern winter and the southern summer. The southern hemisphere being now turned towards the sun, enjoys the greatest amount of sunshine. When it is midwinter in the north, it is midsummer in New Zealand and Australia.

29. At the lower side of the diagram the position of the earth is represented as on the 21st of March, when there is again an equality between the days and nights in both hemispheres. On the 21st of September the ecliptic crosses the equator *descending:* on the 21st of March it again crosses the equator *ascending*. The former is the Autumnal equinox: the latter is the Vernal equinox.

30. As the orbit of the earth is not a circle but an ellipse, as will afterwards be explained, the sun is not exactly in the centre,—and therefore the earth must be nearer to it in one part of its orbit than the other. But, as the earth travels along the portion nearest to the sun in the northern winter, and along the portion furthest from the sun in the northern summer, there is a slight alleviation of the winter's cold and the summer's heat in the northern hemisphere, and a slight aggravation in the southern.

V. GRAVITATION AND THE LAWS OF MOTION.

31. Every particle of matter is attracted by every other particle, and is inclined to fall towards it with greater or less velocity. This kind of attraction is called gravitation, and regulates the movements of the heavenly bodies.

32. The mass of the earth is so great, that, at its surface, a body falls sixteen feet one inch during the first second of its fall. If the mass were greater the fall would be more rapid.

33. The velocity of the fall is the same whatever be the weight of the body falling. For example, a stone weighing one pound will fall to the ground as quickly as a stone weighing twenty pounds. In other words, one pound will fall to the ground as quickly as twenty, whether the twenty be in one piece or in twenty pieces.

34. The force of attraction decreases according to the square of the distance. For example, if one body is attracted to another at the distance of one foot with a force of four pounds, at the distance of *two* feet, as the square of 2 is 4, the force will be diminished *four* times,—that is to say, instead of being four pounds, it will be only one.

35. A body in falling increases in velocity as it falls; the space through which it falls being as the square of the time in falling. For example, a body falling one fathom in one second, will fall four fathoms in two seconds, nine fathoms in three seconds, and sixteen fathoms in four seconds.

36. When a body is propelled by a single blow, it will move in a straight line through equal spaces in equal times, if no other force interfere with its motion. For example, a stone moving ten feet in one second will continue to move in the same direction with the same velocity, unless it be retarded by the resistance of the air, or attracted downwards by gravitation. The continued resistance of the air would gradually exhaust the force with which it had been propelled, and the attraction of the earth would make it move in a curve downwards.

37. A body projected horizontally will fall to the ground at a distance, at the very same moment that it would have reached

it, supposing it to have been dropped on the spot. For example, if one ball be projected horizontally from a high platform, and another ball be allowed to drop from the same platform at the same time, they will both reach the ground at the same instant. This law is illustrated by diagram No. 9. Supposing that a stone were dropped from the platform A, it will have reached the point B at the end of the first second, the point C at the end of the second, D at the third, till it reaches the ground, E at the fourth. Let us also suppose that another stone were projected horizontally in the direction F, it would reach the point G at the end of the first second, H at the end of the second, J at the end of the third, and K at the end of the fourth, provided that the earth's attraction did not draw it downwards; but as the stone that was projected will fall with the same velocity as the stone that was dropped, the two motions will be combined in the curved line A K.

VI. ORBITS OF THE SOLAR SYSTEM.

38. The planets and comets of the Solar system move round the sun, not in circles, but in ovals or ellipses of different kinds. This is a law which was discovered by Kepler, and was proved by Newton to be a necessary consequence of the laws of gravitation, as explained in the previous chapter.

39. The motion of the planets round the sun is produced by the combination of two forces. One is the attraction of the sun called gravitation; the other is a projectile force at right angles to the line of attraction. The former, if alone, would make the planets drop down in a straight line into the sun; the latter, if alone, would send them off in a straight line away from the sun; but both combined make them move in an ellipse.

40. The diagram No. 14 illustrates the combination of the two forces which produces the elliptical orbits of the moon and the planets. Let *a* represent the earth and *b* the moon. Let us first suppose that there is no projectile force, but that the

moon is allowed to drop to the earth, it would then fall in the straight line *c*. Let us next suppose that the moon received an impulse in the direction *d* without being attracted to the earth, it would then move in the straight line *b d*. Let us, in the third place, suppose that the moon receives a slight impulse in the direction *d*, while the earth attracts it by the force of gravitation, it will then move neither in the straight line *b d*, nor in the straight line *b c*, but in the curved line *b e*. Let us, in the fourth place, suppose that it receives a somewhat stronger impulse in the same direction, it will then fall in the line *b f*. Let us again suppose that it receives a still stronger impulse, it will in that case clear the earth altogether, and will come round on the other side, returning to the point *b* from which it set out, and continuing to revolve round the earth nearly in the circle *b g*. Were the impulse to be still stronger, the orbit would assume the form of an ellipse *b h*, the character of which will hereafter be more particularly referred to as one of the conic sections. (*See diagram* No. 8). A still more violent impulse would send it in the line *h k*, which is another conic section called the parabola, (*See diagram* No. 11), by which it would never return to the original point *b*.

41. An ellipse is a section of a cone produced by a plane passing obliquely through its opposite sides. (*See diagram* No. 8). A parabola is a section of a cone parallel to one of its sides. (*See diagram* No. 11).

42. An ellipse may be formed in the following manner: 1*st*, Tie together the two ends of a thread so as to form a loop. 2*d*, Stick two pins in a board and throw the loop over them; and 3*d*, Tighten the loop with a pencil, and draw a figure round the pins as large as the thread will permit. That figure will be an ellipse, and will have this remarkable property, that the two lines drawn from the two pins to any one point will be together equal to the length of the larger axis. The two pins represent the two foci of the ellipse. (*See diagram* No. 10).

43. Diagram No. 10 represents an ellipse. A B are the two foci. C D is the major axis. E F is the minor axis. Two lines drawn, one from each focus and meeting at any one point in the circumference, have their sum equal in every case to the major axis; consequently, all such united lines must be

equal to one another. For example, the two lines meeting at G have their sum equal to those meeting at E, or any other point in the circumference, if they start from the two foci.

44. When a planet or a comet revolves round the sun in an elliptical orbit, the sun is not in the centre of the ellipse, but in one of the foci. In like manner, when a moon revolves round a planet, the planet is not in the centre, but in one of the foci of the ellipse. (*See diagram* No. 16.)

45. The nearer that the two foci of an ellipse are to one another, it approaches the more nearly to a circle. The more distant they are, the eccentricity is the greater.

46. The planetary orbits are nearly, though none are altogether, circular: the orbits of the comets are very eccentric, having their foci at great distances from one another.

47. When a planet is at its greatest distance from the sun, and begins to come nearer, its velocity increases till it arrives at the point at which it is nearest and has its greatest velocity. After that, its speed gradually diminishes until it again reaches the point at which it is furthest distant. In the former case, it is like a pendulum moving downwards, in the other case, it is like a pendulum moving upwards.

48. A line drawn from the focus in which the sun is placed, to the planet as it moves in its orbit, is called its RADIUS VECTOR. The point in the orbit which is furthest from the sun is called its APHELION. The point which is nearest is called its PERIHELION.

49. Kepler discovered that the RADIUS VECTOR, in its journey with the planet round the sun, describes equal areas in equal times. For example, diagram No. 16 represents the orbit of a planet divided into twelve parts, each division showing its motion during one month of its year. The area of each division is the same as that of the others, because the motion of the planet at its PERIHELION is quicker than at its APHELION. This is called Kepler's second law. (*For Kepler's first law, see* No. 38).

50. Kepler also discovered that the time of a planet's revolution bears a certain proportion to its mean or average distance from the sun. That is to say, the *square* of its periodic *time* is proportioned to *the cube* of its mean *distance*. This is called Kepler's third law.

VII. THE MOON—ECLIPSES.

51. The moon travels round the earth in its orbit as the earth travels round the sun. But as the sun shines on only one side of the moon at once, and we do not always see the side which is illuminated, the moon presents different phases to the earth. (*See diagram* No. 17).

52. The moon takes about 28 days to complete its circuit round the earth, and during that time it is continually changing its appearance. When the sun is upon the other side of the moon we cannot see it at all, the bright side being turned towards the sun and its dark side toward the earth. This is called the new moon.

53. As the moon turns away from the sun, we begin to see a little of its bright side, like a thin crescent, which gradually broadens into a half moon (which is its first quarter), and then into full moon (which is its second quarter). From that time it begins to wane, till it becomes again a half moon (which is its third quarter), and then a thin crescent as before, till it disappears altogether and commences again a new moon. These are called the phases of the moon, and are represented in diagram No. 17.

54. When the moon comes between the sun and the earth, so as to hide it either wholly or in part, it is called an Eclipse of the sun. On the other hand, when the earth comes between the sun and the moon, so as to darken the moon, it is called an eclipse of the moon. In the one case the moon casts its shadow on the earth; in the other, the earth casts its shadow on the moon. But as the shadow of the earth is much larger than the shadow of the moon, the eclipses of the moon are much more frequent than the eclipses of the sun.

55. If the paths of the sun and the moon were in the same plane, there would be two eclipses every month; one of the sun, the other of the moon; but as they are not in the same plane, but cross one another at two points, called the moon's nodes, there can never be an eclipse except when both sun and moon happen to be at these points at the same time. The sun

is eclipsed when they are at the same node; the moon is eclipsed when the sun is at one node and the moon at the other.

56. Diagrams Nos. 18 and 19 illustrate the eclipses of the sun and moon. On the left side, No. 18 represents an eclipse of the sun; on the right, No. 19 represents an eclipse of the moon. As the comparative sizes and distances of these bodies cannot be combined in any diagram, great exaggerations have been necessary to illustrate the causes and the effects of an eclipse.

57. Diagram No. 18 represents an eclipse of the sun by the moon casting its shadow on the earth. In the centre of the shadow is a dark spot, upon which the sun does not shine at all. On that part of the earth the eclipse is a 'total eclipse;' but this can take place only when the sun is farther, and the moon nearer than usual. The dark spot travels across the earth, as the moon moves on in its orbit, till the eclipse is past. On each side of the dark spot, or rather round about it, there is another shadow not nearly so dark, called the penumbra; and in all the places over which this penumbra passes there is a partial eclipse of the sun—that is to say, only a part of the sun's disc is hidden. (*See diagram* No. 20).

58. When the sun is nearest to the earth, so as to appear large, and when the moon is farthest away, so as to appear small, the moon does not cover the whole surface of the sun, even when the centre of the one is on the centre of the other. This is called an annular eclipse, because the sun appears in the form of a ring. (*See diagram* No. 21).

59. On the right side, diagram No. 19 represents an eclipse of the moon, by its coming within the shadow of the earth. As the shadow of the earth travels over the moon, the moon is obscured without being entirely hidden from view, until it emerges from the shadow on the other side. As the shadow of the earth is larger than that of the moon, an eclipse of the moon is not only more frequent, but lasts longer than an eclipse of the sun.

60. An eclipse of the moon, wherever it can be seen, appears the same in all parts of the earth, and is seen by all at the same time; but an eclipse of the sun is visible only in some parts of the earth, and does not appear alike to all. To some places,

it may be a total eclipse, in others only partial, while to all the places beyond these there is no eclipse at all. As the shadow must travel over the surface of the earth, the even time of the eclipse must be different in different countries.

61. Diagram No. 20 represents the appearance of the sun during a partial eclipse; No. 22 represents the appearance of a total eclipse. The bright radiance around is called the Corona. There are also red prominences near the surface of the sun.

VIII. THE TIDES.

62. In section No. 31 it was stated that every particle of matter is attracted by every other particle of matter in the universe; and that the force of the attraction increases as they come nearer to one another. For that reason the moon attracts that part of the earth which is nearest to it more powerfully than it attracts the centre, and it attracts the centre more powerfully than it attracts those parts which are furthest away.

63. By this means a tide is raised on BOTH sides of the earth, because the solid earth is drawn away from the water on the farther side, as much as the waters on the nearer side are drawn away from it. They are *all* moved from their places, but they are moved in different degrees. The waters nearest to the moon are drawn *three* degrees, the earth itself is drawn *two* degrees, and the waters furthest away from the moon are drawn *one* degree nearer to the moon.

64. It is evident, therefore, that it is not simply the attraction of the moon that causes the tides, but the *difference* of the attraction at different distances. If the attracting body were at an infinite distance, if that were possible, there might be as much force of attraction, but there would be no tide, because all the parts would be equally near, and therefore equally attracted.

65. For this reason the sun produces a smaller tide than the moon, although the force of its attraction is a hundred times greater. The sun draws the waters of the ocean a great deal higher than the moon does; but as it draws the earth and the waters on the other side, almost in the same proportion, the tide is less, because the difference is less. (*See diagrams* No. 23 and 24.)

66. Upon the same principle, a very small body, if it were near the earth, might produce a gigantic tide that would deluge the earth; not because it would attract the waters more, but because the difference of the comparative distances would be greater.

67. Diagram No. 28 will illustrate the theory of the tides. Let A be a ball of iron representing the earth, and let B and C be small pieces of iron representing the waters on each side of the earth. They are all suspended by threads from the ceiling, so that although they hang freely they touch one another. Let us now suppose that a powerful magnet, representing the moon, is brought to the position occupied by the sun in Diagram No. 25, the immediate effect would be to attract all the three towards the magnet, but in different degrees. The piece of iron B, representing the waters nearest to the moon, would be drawn to the position B′. The ball of iron A, representing the earth, being further from the magnet, would not be drawn quite so far, but only to the position A′; while C, the piece of iron representing the waters furthest from the moon, would be less attracted than either, and would only come to the position C′; proving that there must be a tide on the side farthest from the moon, equal to the tide on the side that is nearest.

68. If the magnet were brought nearer, the three objects would not only be drawn further on by the greater power of attraction, but would also be further separated from one another, because the difference of their distance would be greater in proportion.

69. For the same reason, were the magnet removed to, say, double the distance, the three objects would not only fall back nearer to their original position, but they would also fall closer together. In order still more clearly to illustrate

the theory of the tides, we shall suppose that the magnet is still kept at double the distance, and that the power of its attraction is increased to such an extent that it is able to draw the iron ball to the position A′, it would be found that the iron B would not come so far as B′, and that the iron C would come further than C′. The reason is, that the attracting body being far away, would attract them more equally than when it was near.

70. We have shown that both sun and moon produce tides, but that the tide produced by the moon is much greater than that produced by the sun. They are really different tides; but they sometimes unite to form one great tide, called the Stream tide.

71. Diagram No. 24 represents the two tides separate, the ebb of the one tide counteracting the flow of the other; this is called the Neap tide. Diagram No. 23, represents both tides united, called the Stream tide, in which the ebb and flow of the sun's tide are added to (instead of being deducted from) the ebb and flow of the moon's tide.

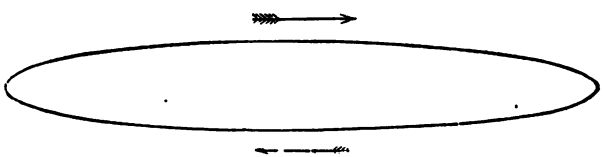
72. The tides are produced by astronomical causes; but when viewed as astronomical effects, they are so exceedingly minute, that if represented upon paper, no microscope would enable us to distinguish them. For that reason, the tides are enormously exaggerated in the diagrams. The difference between 8000 miles of the earth's diameter and a few feet of water is so great, that it is only because man is astronomically a microscopic animal upon the earth, that he is able to observe them.

IX. RETROGRADE MOTION OF PLANETS.

73. If we could stand upon the sun and see the planets travelling in their orbits, they would appear to us to move round the heavens in perfect symmetry and order; for although, like the hands of a watch, they have different velocities, the motion of each would, on the whole, be uniform. But as the

earth on which we dwell is constantly changing its position, their motions, as seen by us, appear to be very irregular. Sometimes after moving rapidly along, they gradually slacken their pace, stand still, move backwards, and then, after again standing still, again travel onwards on their journey as before. This is called the retrograde motion of the planets.

74. In regard to Venus and Mercury, which are nearer the sun than the earth, it is easy to understand how this should be the case. Mercury, for example, is always near the sun; and as the sun appears to travel round the whole heavens every year, Mercury must travel with him. But supposing the sun to stand still, we should see Mercury circling round the sun in its orbit, so as to appear going forward during one half of its revolution, and going back during the other half in a very flattened ellipse, thus—



It is evident that if we combine this motion with our own journey round the sun, we should see Mercury, not travelling like the sun, in a straight line, but travelling in a series of loops thus—

75. The same appearance is presented by the outer planets, as illustrated in diagram No. 25. Let *a* represent the earth in its orbit round the sun; let *s* be the superior planet travelling more slowly in its orbit. It is evident that when they come into conjunction, and when the earth passes its more sluggish companion, the path of the superior planet will take the form of a loop, as at *l*.

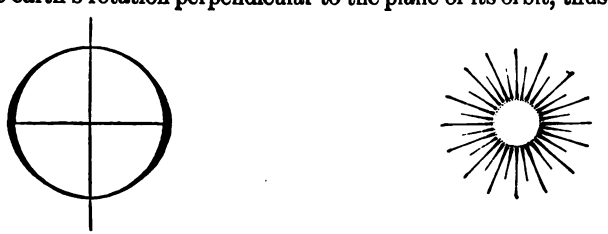
X. PRECESSION OF THE EQUINOXES.

76. In the last chapter, we have seen that the tides are produced by the sun and moon attracting the side of the earth nearest to them more strongly than they attract the side furthest away. There are other effects produced by the same cause, which we will now shortly describe.

77. The earth is not a perfect sphere, being flattened at the poles like an orange, and swelling out at the equator. This swelling at the equator produces a remarkable effect on the motions of our planet, in consequence of its axis not being perpendicular.

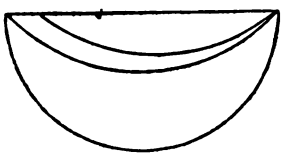
78. This excess of matter being higher on one side of the ecliptic, and lower on the other side, is unequally attracted by the sun and moon; and if it were water it would rush up to the ecliptic on one side, in order to be nearer to the sun, and down to the ecliptic, on the other.

As the excess of matter, however, is not water, it cannot move, but the tendency is the same; and therefore the sun and moon draw the equator towards the ecliptic, tending to bring the axis of the earth's rotation perpendicular to the plane of its orbit, thus—



79. This would be the necessary effect on the earth were

it not that it revolves on its own axis, and thus enables every particle on the equator to yield to this attraction without altering the inclination of the poles. But in doing so, the earth is drawn a little sideways, so as to meet every particle on the equator before it has completed its half revolution. The journey is thus shortened, and the arc, which every particle describes, is less, and therefore nearer to the ecliptic. In this way the



poles are continually yielding to this force, by moving sideways in a circle; but the movement is so slow that it requires 24,450 years to complete it. This is called the precession of the equinoxes. It has been necessary, in these diagrams, to exaggerate the differences to an enormous extent, because otherwise they would not be visible.

80. It is a remarkable circumstance that this twofold motion of the earth is illustrated by the twofold motion of a child's top. When a top is made to spin, it not only turns rapidly upon its own axis, but its axis also revolves slowly in a circle, as shown in diagram No. 31. This second motion is produced by the very same cause that produces the revolving of the poles of the earth, as shown in diagram No. 32.

81. This revolving of the earth's axis, in order to make the equator meet the ecliptic a little sooner than it would otherwise do, has the effect of making the crossing points (that is the equinoxes) move onwards. This is illustrated in Diagram 33. A is the pole of the ecliptic, round which the pole of the earth *c* revolves in the waved circle *f*—*f*. The circle BB represents the ecliptic; and as the pole of the earth changes its position, the point at which the equator *d* crosses the ecliptic must also change. As the distances of the stars are measured from the spring equinox, astronomers must always make allowance for this change. Two thousand years ago the spring equinox was in the sign Aries; it is now in the sign Pisces.

XI. NUTATION OF THE POLES.

82. We have shown that the precession of the equinoxes is produced by the same cause as that which produces the tides; but there is another point of resemblance, because the 'NUTATION OF THE POLES' might be called the stream tide and neap tide of the precession, and these take place every nineteen years.

83. If the path of the sun and the path of the moon were in the same line, the precession of the equinoxes would be the only effect produced by the excess of matter at the equator; but as the moon has a period of nineteen years, during the first half of which it is more distant from the equator than it is during the other half, the consequence is, that during the first half it is able to draw the equator further than it can do during the other half.

84. The effect of this is to give a nodding motion to the pole, and to make a waving line in its circuit round the pole of the ecliptic. The plain circle is thus converted into a figure like a toothed-wheel, with as many teeth as there are nineteen years in 24,450. (*See Diagram* No. 33.)

XII. THE HARVEST MOON.

85. In autumn, when the days and nights are equal, the sun sets at six o'clock, and the full moon rises at the same hour, so that at that season the sky is never dark. If it continued so, it would be exceedingly convenient for the farmer, because it would enable him to continue his harvest operations after the sun had set.

86. But although the sun takes 365 days to travel round the heavens, the moon completes its journey in 28; so that, on an average, it rises 52 minutes later every day. If, therefore, the full moon rose at six o'clock one day, it would not rise till about seven the next, a quarter before eight the third

day, and so on, so that the farmer would be in darkness at sunset.

87. In autumn, however, as if to benefit the farmer, and enable him to gather in his harvest speedily, the moon rises for several days at nearly the same hour, and this is what is called the Harvest Moon, the explanatian of which is as follows:

88. We have said that the moon travels round the heavens in about 28 days, and, therefore, if her orbit were parallel with the equator, she would rise regularly 52 minutes later every day. But as her orbit is not parallel with the equator, the difference in the time of rising is at one part much more than 52 minutes, and at another time much less.

89. In diagram No. 26 we see the moon's orbit crossing the equator at the *autumn* equinox, at a very great angle: its downward progress in its orbit therefore is very steep and rapid; so that the earth has every day to revolve a great deal further to meet it, and thus the difference in the time of rising is much *more* than 52 minutes.

90. In diagram No. 27 we see the moon's orbit crossing the equator at the *spring* equinox at a very small angle, so that its progress is neither steep nor rapid, and therefore the earth in its revolution meets it at nearly the same hour every day.

91. Now, when the moon happens to be full when crossing the equator at the *spring* equinox, rising nearly at six o'clock every night, the sun must be in the *opposite* equinox—that is, the *autumnal;* and as that happens on the 23d September, the harvest moon must always be within a fortnight of that day.

XIII. THE REFRACTION OF LIGHT.

92. A ray of light coming from a star and entering the earth's atmosphere is bent downwards, causing the star to appear, to the eye of an observer, as if it were higher than it really is. This is caused by what is called the refraction or

bending of the rays of light when passing from a rarer to a denser medium, or from a denser to a rarer medium.

93. The atmosphere by which we are surrounded decreases in density as it ascends, until, at a distance of from fifty to a hundred miles, it altogether disappears. Beyond that height the medium through which light travels is called Ether. As the density of the atmosphere increases with its depth, the refraction of the rays of light from a star increases as it approaches the earth, as represented in diagram No. 35. The rays of light coming from the star A, on entering the earth's atmosphere, are bent downwards until they reach the eye of an observer at B; but, on account of the direction in which the rays come to him, the star appears to be higher than it really is. It seems to him as if it were at C, whereas it is really at A.

94. A very simple illustration of the refraction of light is shown in diagram No. 36. Put a coin at the bottom of a basin, and retire from it till it disappears, on account of the rays being intercepted by the side of the basin. Pour in water, and the coin will reappear, as if it had been lifted up into sight. This effect is produced by the rays of light from the coin being bent or refracted, on coming out of the water into the air.

95. The same effect would have been produced if, instead of water, the basin had been filled with glass, or if the coin had been covered with a thick plate of glass. Diagram No. 37 represents the section of a lens, by which the rays of light are refracted at different angles (according to the surface at which they enter and come out), so as to be gathered and concentrated at a single point. The sun's rays may, by means of a lens, be concentrated on one point, so as to produce intense heat.

96. White light (that is, colourless light) is composed of rays of many different kinds, and may be opened out like a fan, by being sent through a prism. (*See Diagram* No. 38.) The different rays are subject to different degrees of refraction. The red rays seem to go with more force than the others, as they are least bent on passing through a prism. After them are the orange, then the yellow, green, blue, purple, and violet rays, which are most of all refracted. This is called the dispersion of the rays. There are other rays, however, besides

the rays of light. Beyond the red rays are the caloric or heat rays; and beyond the violet rays are the actinic, or rays of chemical power.

XIV. TELESCOPES.

97. There are two kinds of telescopes, refracting telescopes and reflecting telescopes. In the refracting telescope, the light is made to converge by passing through lenses of different kinds; in the reflecting telescope, the light is reflected from a speculum or concave mirror, so as to bring the rays into a focus.

98. Diagram No. 34 illustrates the general principles upon which a refracting telescope is made. The telescope consists of two lenses, E and H. E is called the object-glass, and H the eye-glass. An object at a distance is supposed to send its rays to the object-glass E. The rays from the top of the object are A B. The rays from the bottom of the object are C D. The rays A B are refracted to a focus at F, and the rays C D are refracted to a focus at G, so that a perfect image of the object is formed at G F, but it is turned upside down. By means of the eye-glass H, the focus of which is at G F, the eye can see the image of the distant object as if at G F.

99. A reflecting telescope is made by placing at the bottom of a closed tube a metalic speculum highly polished and concave, to receive and reflect the light that enters the tube. The rays are reflected so as to converge to a point or focus at the upper end where the image is formed. A small mirror placed obliquely at that point reflects the image to the side, where it can be viewed by an eye-glass through a hole made for the purpose.

100. An improvement was suggested by Le Maire, which dispenses with the mirror at the upper end. The speculum is turned a little, so as to send the image to the side instead of to the centre of the tube, and by this means, the image being viewed directly, is much brighter and more distinct.

101. Lord Rosse's reflecting telescope is the largest and most powerful in the world. The speculum is six feet in diameter, and weighs nearly four tons. Its focus is fifty-four feet distant from the speculum, and by its means we can see into the heavens five hundred times farther than by the naked eye. A view of this telescope is given in diagram No. 30.

XV. ABERRATION OF LIGHT.

102. What is called the aberration of light is a change in the apparent position of a star, caused by the motion of the earth.

103. When a child is seated on a swing, although the air may be perfectly calm, he feels as if the wind were blowing in his face when he swings forward, and blowing on his back when he swings backward. The air does not move toward him, but, as he moves toward the air, the effect is exactly the same.

104. In like manner, if we stand still when it is raining, we hold the umbrella perpendicularly to escape the rain. (*See Diagram* No. 40.) But if we run, we point the umbrella forward; because, although the drops fall perpendicularly, the effect to us is the same as if they fell in a slanting direction. (*See Diagram* No. 39.)

105. Light travels with great velocity, but it is not instantaneous. When therefore the shower of rays falls from any part of the heavens while the earth is in motion, we must point our telescopes (very slightly) in the direction in which the earth is travelling, in order to catch any one of them.

106. This is illustrated in diagram No. 41. Supposing that a ball were dropped over a tube which is at rest, the tube must be perpendicular in order to receive it as it falls. But let us suppose that the tube is mounted on a carriage, and that the carriage is in rapid motion, it is evident that we must point the

tube in the direction in which the carriage is travelling in order to allow the ball to pass through it without touching its sides. As regards the ball itself, it is falling perpendicularly, but as regards the moving carriage, it is falling obliquely. So it is in regard to the rays coming from any of the stars; as regards the rays themselves, they are falling in a direct line; but as regards the earth, which is in motion, they are falling obliquely in the direction in which the earth is travelling.

107. As the path of the earth is not straight, but circular, the telescope must turn round in a circle, or ellipse, to follow each star; and for that reason the star appears to move in an excessively minute ellipse, although it is really standing still. If the earth were to stop, the star would instantly appear in the *centre* of the ellipse.

XVI. PARALLAX.

108. When we are travelling on a road, the objects on either side appear to be changing their position as we move along. On one side, a star is shining directly over the top of a hill; while a tree is exactly between us and both of them. But as we move forward, the tree is left behind, while the star and the hill appear as before. After some time, however, as we proceed, the hill also is observed to be moving away from under the star, and the star alone retains its original place. By this means we know that the tree was nearer than the hill, and that the hill was nearer than the star.

109. This illustrates what is called Parallax, which means, *the apparent change of position which any object undergoes when viewed from two different points of observation.*

110. By means of parallax we can calculate the distance of any object, even though it be beyond our reach, provided that we know the distance between the two points of observation. For example, in diagram No. 42, the height of the tower D may be measured by comparing the angle D B A with the angle

D A B, provided that the length of the line A B (called the base line) has been accurately ascertained.

111. If the tower be near, the difference of the angles will be great, if it be far away, the difference will be small. In like manner, if the base line be short, the difference between the angles will be small; whereas, if it be long, the difference will be great. For that reason, it is of importance to get long base lines in order to measure great distances.

112. The star C is so distant that the base line A B is too short to measure it, because, when viewed from either point, the angle is the same. If we attempt to measure the distance of a star, we must have a much longer base line; that is to say, we must find two places for observation which are sufficiently distant from one another. But there are no two places on earth sufficiently distant from one another to enable us to measure the distance of a star; and yet the distance of the moon has been very accurately measured in this way.

113. What is called the *Diurnal Parallax* provides a longer base line than any two places on earth, and is obtained by means of the rotation of the earth on its own axis. The base line of the diurnal parallax is the distance travelled by an observatory during so many hours of the earth's rotation. The longest line obtained by this means is the diameter of the earth at the equator, which is nearly 8000 miles.

114. In diagram No. 42, the semicircle A E B represents the motion of the earth during one-half of its revolution, and, in that connection, A B is the base line which stretches between the position of the observer at six o'clock in the evening, and six o'clock in the morning, and which is several thousand miles long. It was by such a base line that the distance of Mars was discovered.

115. The *Annual Parallax* gives a still longer base line, and is the longest possible. It is the diameter of the earth's orbit round the sun, as represented under diagram No. 42. The length of this base line is 122,000,000 of miles; and by travelling with the earth in its orbit, and viewing a star first in July and afterwards in December, or first in March and afterwards in September, we get two views, one at F, and the other at G.

116. Yet so great is the distance of the vast majority of

the stars, that even with this enormous base line, the angle is unchanged; that is to say, the base line is too short to show any parallax. These stars, therefore, must be many millions of times further away from the sun than we are.

117. But some of the stars do shew a parallax; and by means of that parallax their distance can be measured. The nearest fixed star which has yet been discovered is *a* Centauri, but the distance of even this, the nearest, is almost inconceivable, being not less than 224,000 times greater than that of the sun.

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I. METEORIC PHENOMENA.

1. Shooting stars and other meteors were formerly supposed to be the productions of our own atmosphere; it has now been fully ascertained, that they do not belong to our planet, but are loose materials floating in the Solar System, and falling to the earth on coming within the influence of its attraction.

2. There is reason to believe that meteoric substances are sprinkled, not only over the Solar System, but generally through space; and that under the influence of gravitation, and, it may be other forces, they have arranged themselves into groups or systems, many of which forming elliptical trains or rings, are now travelling round the sun in every possible direction. (See Chart, No I., (Figure 37.)

3. The magnificent star shower which was seen on the night of 13th November 1866, and which is represented in Figure 5, was caused by the earth on that evening passing through one of these trains at the part which was the most densely crowded with meteoric matter. This ring or train has a period of revolution of about 33¼ years, and therefore although we have a star shower in November every year, the next great star shower will not take place till 1900, when the dense portion of the train will again cross the earth's orbit.

4. The luminous appearance of the falling stars is caused by their taking fire on coming in contact with our atmosphere.

Having a velocity of about thirty miles a second, as soon as they arrive within 74 miles of the earth, the heat produced by their friction, in passing through the air, is so great that they immediately become incandescent, their velocity is retarded, and on coming within about 50 miles from the earth they disappear.

5. While the earth is passing through the meteoric train, the point towards which the earth is travelling is the point from which the shooting stars seem to radiate; and as the earth on that day is flying in its orbit in the direction of Leo, the radiating point of the November meteors is in that constellation. (See Figure 6.)

6. Astronomers have counted upwards of fifty different periodical star showers, having different radiating points; and it is supposed that each of these is produced by a separate group or train of meteorites. It has also been observed that these star showers are not all alike, but have each its own peculiar character and appearance. Some consist of larger and brighter meteors than others. They also differ in colour and velocity.

7. Besides the shooting stars there are other kinds of meteoric phenomena. Some single meteors are so bright that they have been seen in day light, some of them exploding with a deafening noise. Some are so dense that they fall to the ground without taking fire, and are found to consist of solid iron and other metals. These heavy bodies are called meteoric stones, and generally vary in size from a few ounces to as many pounds. Others are of great magnitude. Mrs Somerville mentions one which passed within 25 miles of the earth, and was estimated to weigh about 600,000 tons. It had a velocity of about twenty miles in a second.

II. THE ZODIACAL LIGHT (Fig. 1).

8. This name is given to a peculiar glow in the sky which is occasionally visible in this country in the evenings of spring and the early mornings of autumn; but in tropical countries it is seen at all seasons of the year, before sunrise and after sunset.

9. It stretches up from the horizon, where it is broadest, in a pyramidal or lenticular form, directly over the place where the sun has set or is about to rise; and although its nature is not perfectly understood, it is generally supposed to be produced by the light of the sun illuminating a great system of meteoric matter which revolves round the sun, and which extends beyond the orbit of the earth.

III. LUNAR MOUNTAINS (Fig. 4).

10. The moon when seen through a telescope has a very beautiful appearance, and is represented in Chart No. I., Figure 32. On the lower part of the disc towards the right is a bright circular spot, which is the mountain Tycho. From that as a centre there are bright streaks radiating all around, suggesting the form of a sphere with meridian lines.

11. The darker portions of the moon's surface are extensive plains, having in general a circular boundary; but the characteristic formations of the moon are ring mountains of different sizes, which, when viewed through a small telescope, appear like rings of burnished gold.

12. The general appearance of the lunar mountains is represented in Figures No. 35 and 36, Chart I., and No. 4 of the present Chart. No. 4 is a characteristic specimen of the smaller formations which abound in the lower part of the moon's disc. All of them have a volcanic appearance, resembling the craters of our own volcanoes. So different are they, however, from volcanoes of our own world, that we cannot be sure that they are produced by the same causes. These lunar craters are very much wider than those of earthly volcanoes, and are never on the tops of mountains. The interior plain also is lower than the general surface of the moon, suggesting that they had been formed during the time that the outer crust was hardening, and after the liquid interior had begun to shrink in bulk while cooling.

IV. STRUCTURE OF THE SUN'S DISC (Fig. 2).

13. The surface of the sun consists of one vast globular sheet of flame called the photosphere. Beneath the photosphere there are other cloudy strata, the nature of which is yet unknown.

14. The photosphere is not one continuous sheet of flame, but is made up of innumerable single flames, shaped like willow leaves, rice grains, and other irregular forms. Their length may be about a thousand miles and their breadth a hundred. For this discovery we are indebted to the observations of Mr James Nasmyth of Penshurst, who has kindly supplied the drawing Figure 2, representing a solar spot.

15. The spots on the sun are holes in the photosphere which enabled us to look down into the interior, where we can observe different shades of darkness with a dark nucleus in the centre. Even this nucleus, however, is not black, although it appears so in comparison with the dazzling photosphere with which it is surrounded. The lighter shade of the spot next the photosphere is called the penumbra, and the darker shade next the nucleus is called the umbra.

V. TOTAL ECLIPSE OF THE SUN (Fig. 7).

16. Figure No. 7 represents a total eclipse of the sun, during which we are enabled to observe a very extensive but excessively thin atmosphere surrounding the sun. This illuminated atmosphere is called the Corona, and shines partly by its own light and partly by the reflected light of the sun.

17. This corona is not uniform all round. Not only are there bright rays stretching far out, but there are dark rifts reaching down towards the sun.

18. There are also rose coloured prominences shooting up from the surface in fantastic forms, many thousands of miles high. These rose coloured flames have been ascertained to consist of incandescent hydrogen, and belong to a luminous

stratum surrounding the sun, called the chromosphere. The rapidity with which these rose coloured flames change their place and form, indicates a state of commotion on the sun's surface, the violence of which it is almost impossible to conceive. Lockyer describes one of these enormous jets which rose 27,000 miles high, and disappeared in ten minutes. The general height of the chromosphere from which they rose is about 5000 miles high. In Figure 3 will be found specimens of these rose coloured flames.

19. Besides the chromosphere, there is another envelope consisting of non-luminous metalic gas, lying above the photosphere, and absorbing its rays. It is by means of this stratum that we are enabled to discover the various substances present at the sun's surface, as will now be explained.

VI. SPECTRUM ANALYSIS (Fig. 31).

20. It has already been explained, in connection with Chart No. II. (Astronomical Diagrams), that a prism has the power of refracting—that is, bending—the rays that pass through it so as to throw upon a screen beyond it a spectrum or band of coloured light corresponding with the hues of the rainbow,—red, orange, yellow, green, blue, indigo and violet,* as represented in No. 31.

21. The reason why these rays are separated is, that while

* The rays of colour are not capable of acting on any substance in nature with which we are acquainted, except the Living Eye of an animal. But there are other rays proceeding from the sun which are not visible, and which prove their existence and power by the wonderful changes which they are continually producing upon nature. There are the rays of Heat, which fall beyond the red rays at one end of the spectrum, and the Actinic rays, which fall beyond the violet rays at the other end. The eye, therefore, is perhaps the most remarkable and conclusive proof of an omniscient, intelligent, and beneficent Creator; because, before He made the eye He must have known of the existence of these colour rays, of which all nature was then unconscious, and of their power to affect a peculiar kind of animal tissue, which He then made on purpose. —Ps. xciv. 9.

light consists of many rays of different colours, some of which are more easily refracted than others. The red rays, which are not easily refracted, go in nearly a straight line, whereas the violet rays, which are most easily refracted, are bent furthest from the straight line.

22. When a lime ball is heated to brilliancy by the oxy-hydrogen blowpipe, the light which it sends out consists of an infinite variety of rays, possessing every variety of refrangibility.* The consequence is, that when it is seen through a prism, the spectrum is continuous; that is to say, every degree of refrangibility, and every shade of prismatic colour, is represented, without any blank in the whole range.

23. But it is not so with light emitted from any incandescent gas, or from any solid or liquid body reduced to a state of gas. That kind of light does not give a continuous spectrum, but only particular rays, which fall upon particular parts of the spectrum, according to the particular substance which gives out the light. For example, in Figure 31 are represented the rays proceeding from the combustion of Iron, Sodium, Lithium, Nitrogen, and Hydrogen, every one of which differs from every other, and therefore if in the spectrum of any flame we find these lines of colour, we may be certain that the substance to which they exclusively belong is present in that flame.

24. There is still another fact, however, to which we must call attention. Not only has every gas the power of *giving out* particular rays, it has also the power of absorbing or intercepting the same rays when light is passed through it—that is to say, if we send white light through the vapour of any substance, instead of producing its own peculiar lines coloured upon a black ground, the absorbing vapour intercepts the rays which correspond with its own rays so as to produce these black lines upon a coloured ground. By this means we are able to discover not only what substances are producing the light, but also what substances are intercepting it.

* Not only the light from the lime ball, but light emitted by a candle or gas flame, or any solid or liquid body, so long as it is liquid or solid, has also a continuous spectrum.

25. Astronomers have for some time been engaged in examining the light which comes from the different heavenly bodies, and they have discovered that, with few exceptions, the rays coming from these distant orbs are identical with the light produced by well known substances on earth.

26. The light which comes from the sun has been examined with instruments of great precision, which have produced the spectrum eleven feet long, and which have shown in that spectrum several thousands of dark lines, every one of which has its peculiar position, and indicates the presence of some particular substance in the sun's atmosphere; 470 of these lines belong to iron alone.

27. Besides the iron it has been found that sodium, magnesium, barium, copper, zinc, calcium, chromium, nickel, manganese, cobalt, titanium, and hydrogen, are also present in the sun's atmosphere. But as the lines are black upon a coloured ground, they must be produced by the light passing through an outer envelope containing these substances, each of which absorbs or intercepts its own kind of rays, so as to prevent them from appearing in the spectrum.

28. The light proceeding from the moon and the planets has been examined by the same instruments, and it has been found that the same lines appear in their spectra that are found in the spectrum of the sun. The reason is, that it is the sun's light that is reflected from them.

29. The spectra of the fixed stars resemble that of the sun in having dark lines upon a coloured ground; but the lines are not the same. Some of the substances found in the spectrum of the sun do not appear in them; and some of the substances found in them do not appear in that of the sun. The following are specimens. (See Figure 31.)

30. The spectra of the true nebulæ differ from those of the stars. Instead of having dark lines on a coloured ground, they have coloured lines on a dark ground, showing that the light comes directly from incandescent gases, without having to pass through any gaseous atmosphere which would intercept or absorb any portion of it.

VII. DOUBLE AND COLOURED STARS.

31. A large number of the fixed stars when viewed through the telescope are found to be double. That is to say, there are two stars so close together that they appear to the naked eye to be only one. In general there is a large star with a small companion near it, but there are also some in which the two are nearly of equal magnitude. Many of these double stars present also striking contrasts of colours, one of the two being perhaps red and the other green; or, one being white and its companion purple.

32. There are also apparently single stars, which consist of three, four, or even a greater number of constituents. They are called triple, quadruple and multiple stars, when they are associated together in a single system. Upwards of 6000 compound stars have been discovered, and of these nearly 700 have been observed to change their relative positions, showing that they revolve round one another, or round a common centre of gravity. Some complete their revolutions in short periods, others in very long periods. One double star ζ Herculis, for example, has a period of thirty-six years, whereas the system of ϵ Lyræ has been computed to have a period of nearly a million of years.

VIII. DIAGRAMS OF THE COMPOUND STARS.

33. FIGURE 10 represents the orbit of the companion star of γ Virginis, with a period of about 170 years.

34. FIGURE 11 α Cassiopeæ. The larger star is a pale rose colour, the smaller star blue.

35. FIGURE 12 σ Pisces; a triple star. The largest star is yellow, the second blue, and the third ruddy.

36. FIGURE 13. ϕ Tauri. The larger star is red, the smaller star blue.

37. FIGURE 14. η Persei. The larger star is orange, the smaller star blue.

38. FIGURE 15 represents the orbit of the companion star of ζ Herculis, with a period of thirty-six years. The larger star is yellowish white, the smaller star is of an orange tint.

39. FIGURE 16 β Orionis. The larger star is pale yellow, the companion is sapphire blue.

40. FIGURE 17 α Scorpionis. The large star is red, the small star bluish green.

41. FIGURE 18 γ Andromedæ. The larger star is deep yellow, the smaller star sea green.

42. FIGURE 19. 94 Aquarius. The larger star is rose colour, the smaller star green.

43. FIGURE 20. η Cassiopeæ. The larger star is white, the smaller star pale blue.

44. FIGURE 21. ψ Cassiopeæ a triple star. The largest star is orange, the smaller star blue, the smallest star ruddy.

45. FIGURE 22. 95 Herculis. The larger star is green, the smaller star cherry coloured.

46. FIGURE 23. ε Boötis. The large star is pale orange, the small star sea green.

47. FIGURE 24. The multiple star ε Lyræ. As seen through an opera glass it appears a double star. As seen through a small telescope it appears a triple star. As seen through a powerful telescope it appears a multiple star. The smaller pair is supposed to have a revolution of about a thousand years, the wider pair a revolution of about two thousand, and Admiral Smyth conjectures that the whole system may have a period of something less than a million.

48. FIGURE 8 represents the well known group of stars in the constellation Taurus, called the Pleiades. The largest star in this group is called Alcyone.

IX. PROPER MOTION OF THE STARS.

49. Although we distinguish between the planets and what are called the fixed stars, it has been found that in reality all the stars are in motion, and astronomers have been for a long

time engaged in discovering in what direction each star is moving, and what is its rate of motion.

50. It has been ascertained, in the first place, that our own sun is in motion, carrying with it its attendant planets, and travelling in the direction of the constellation Herculis. For that reason the stars that are at each side and nearest to us, appear to move the most rapidly in the opposite direction. The stars in front appear to open up as we approach, and those behind us are drawing closer together.

51. But besides this apparent motion of the stars, each star has its own proper motion, and it has been observed that there are groups that move in company, each group moving in its own direction.

52. FIGURE 9 represents the stars in Ursa Major, generally known as Charles Wain, or the Plough. There are three distinct companies travelling in different directions, each company being coloured not according to the colour of the stars themselves, but to distinguish the companies according to the direction in which they are travelling. The red stars are travelling to the left, the blue towards the right, and the yellow also to the right, but downwards.

X. VARIABLE STARS.

53. Many stars have been observed to change in brightness periodically. These are called Variable Stars. In some the changes which they undergo is very great, in others it is barely perceptible. The period of the change also is very different in different stars; for example β Persei passes through all its variations in less than three days, whereas ψ Leonis has a period of many years. It is probable that what are called new stars, lost stars, and temporary stars, belong to the same class, but have much longer periods of change. The cause or causes of the variation have been conjectured but not ascertained.

54. In 1572 a new star appeared in Cassiopeæ, which con-

tinued visible for seventeen months, and was so bright that it could be seen at noonday. It is conjectured that this star has a period of 314 years, and if so, will again appear in 1886.

55. FIGURE 25 represents η Argus, varying from the first magnitude to the fourth, with a period of 46 years.

56. FIGURE 26 represents α Ceti (*Mira*) varying from between the first and second magnitude to the fourteenth, with a period of 231 days.

57. FIGURE 27 represents β Persei, varying from the second magnitude (nearly) to the fourth magnitude, with a period of 2 $\frac{9}{10}$ days.

58. FIGURE 28 represents β Lyræ, varying from the third magnitude to the fifth, with a period of $6\frac{1}{3}$ days.

59. FIGURE 29 represents R. Cephei, varying from the fifth magnitude to the eleventh, with a period of 73 years.

60. FIGURE 30 represents R. Cassiopeæ, varying from the sixth magnitude to the fourteenth, with a period of 435 days.

XI. COMETS.

61. In connection with Chart No. I., the general character and appearance of Comets, as part of the Solar System, have been described. We shall now examine them more particularly as Celestial objects.

62. Comets are hazy cloud-like bodies, which sometimes appear in the heavens, and have, in all ages, excited the wonder, and sometimes the superstitious fears of the nations. They are by far the largest, the lightest, and the most irregular of all the heavenly bodies. One was seen so large that it was equal to the distance between the sun and the earth; many of them are so light, that the entire mass would not weigh more than a few tons, and they are so eccentric, that many of them visit the solar system, and after turning round the sun, fly away never to return.

63. Very little can be said of them that would hold true of them all; for although in general each of them has a single

tail, some have two or even more, and not unfrequently they have no tail at all. In general the tail points away from the sun both in going and returning; but even this is not without exceptions, because some have been observed having their tails pointed in quite another direction. One comet was observed to split into two parts which never were reunited; and another, after giving promise of returning at a certain time, disappointed the expectation of astronomers, and has never been seen again.

64. THEIR APPEARANCE is very varied. Some are called Telescopic Comets, because they are so small that they cannot be seen by the naked eye. (See Figure 39.) Others are so large as to occupy a very large space in the heavens. In general they consist of three parts, the head or coma, the nucleus within the head, and the tail.

65. THEIR COMPOSITION is not certainly known, further than that carbon has been detected in spectrum analysis to be present in the nucleus; and, as they move according to the laws of gravitation, they must consist of ponderable matter. The most probable conjecture is, that the head consists of a widely scattered shoal of meteoritic substances, travelling rapidly through space, each little meteorite being many miles distant from its companions; and that the tail is nothing more than the ether of the solar system faintly illuminated by a very feeble discharge of electricity from the head acted on by the sun's rays. The light given out by a cubic mile of the comet's tail amounts to *almost* nothing, and requires to be multiplied hundreds of thousands of times, the one behind the other, in order to produce the dim light which we see, and which, were we near it, would be quite invisible. If it were a gas or an atmosphere, even though it were a thousand times rarer than the air we breathe, it would shine as brightly as the moon by the reflected rays of the sun. The same might be said of the head of the comet, through which even small stars are visible.

66. Unlike the planets, the comets have no connection with, or relation to one another. They have no common ecliptic, but have the planes of their orbits lying in every position. At the same time, as they obey the laws of gravitation, the orbit

of every one of them corresponds with some conic section, either an ellipse, a parabola, or a hyperbola, as explained in Chart No. II. If they are ellipses, they belong to the Solar System, but if they are parabolas, or hyperbolas they are only chance visitors, and will never return.

67. In general, Comets are named after those who either discovered them, or calculated their orbits, as Halley's Comet, or Encke's Comet. Others are called by the year on which they appeared, as the Comet of 1744, or the Comet of 1811.

68. Specimens of Comets. In Figures No. 32 to No. 37, are represented the changes which took place in Halley's Comet in 1835 and 1836. Figure No. 32 shows one of the appearances which it presented before reaching its perihelion* in 1835. Figure No. 33 represents the form which it had when it reappeared after passing its perihelion. At first it was circular, but gradually one of the sides opened, and a tail began to be projected, which increased in size as it receded from the sun, as presented in Figures 34, 35, 36, 37.

69. Figure No. 38 represents Encke's Comet, which appeared in 1823, without a tail.

70. Figure No. 39 represents a telescopic Comet, also without a tail.

71. Figure No. 40 represents the comet of 1861. Although it was comparatively a small Comet, being only about twenty millions of miles long, it was so near to the earth that it occupied in length 70 degrees of the heavens, which is more than one-third of the whole arc.

* Perihelion means that part of an orbit in which it is nearest to the sun. Aphelion that part which is furthest away.

72. FIGURE No. 41 represents the Comet of 1744, which was nearly of the same size. It occupied 44 degrees of the heavens, and was remarkable on account of having seven tails.

73. FIGURE No. 42 represents Donati's Comet of 1858. It was nearly of the same size as the other two, and occupied 40 degrees of the heavens.

74. The Comet of 1811 was one of the largest which has visited the Solar System, being a hundred millions of miles in length, but it was so distant from the earth that it occupies only 27 degrees of the heavens. (See Figs. No. 43 and 47).

75. In Figures Nos. 40 to 43, are represented the comparative sizes of these four comets as they appeared to us. In Figures Nos. 44 to 47 are represented their real sizes comparatively.

XII. THE MILKY WAY.

76. Besides the stars which we see on a clear moonless night, we may observe an irregular band of pale light, which stretches round the whole heavens in both hemispheres, and which is called the Galaxy, or Milky Way.

77. This great system is composed of an almost infinite number of minute stars, too distant to be seen individually, and it is to this system that our own sun, and the stars which appear in our firmament belong.

78. Sir William Herschel supposed that creation is composed of an immense number of such universes, thousands of which are seen in the heavens as patches of pale light called Nebulæ; and that the Milky Way is the nebula to which our sun and the other fixed stars which we can see, belong.

79. Following up this idea he endeavoured to ascertain its form, as it would be seen from a distance, by observing in what parts the increased brightness of the Milky Way indicated an extension of its depth. Figure No. 48 represents the form which he assigned to it, supposing our own sun to lie near the centre.

80. Since that time the subject has received more careful consideration, and his son, Sir John Herschel, has modified his father's theory, by supposing that the Galaxy is not a disc, but a ring split on one side. Mr Proctor suggests figure 49 as a more likely form than either the disc or the ring. The sun is supposed to be situated at the point S. In the direction *a* he accounts for the blank in Argo, which cannot be accounted for by either Sir William's or Sir John's theory; and in the direction *b* he accounts for the double stream, which was previously accounted for by a split. Mr Proctor, however, admits that his is only one of many which might be suggested.

XIII. CLUSTERS AND NEBULÆ.

81. Clusters of stars are scattered over the heavens in immense variety, each consisting of hundreds, thousands, or

perhaps even millions of suns. To the naked eye they appear to be only bright patches of light; but when viewed through a powerful telescope, they are resolved into separate stars.

82. Of those, the most generally known is the Pleiades, in the constellation Taurus, and in this cluster the naked eye can count at least six stars. F. de Rheita has counted 188 seen through the telescope. As specimens of the larger cluster, Figure 50 represents *a* Centauri, and Figure 51 M. Herculis, two of the most magnificent clusters in the heavens.

83. The word Nebula, which in Latin means a cloud, is applied to any stationary object in the heavens which has the appearance of a cloud. Many of these are simply clusters of stars, which can be resolved into separate stars by the telescope; and at one time it was supposed that all the nebulæ were in reality star clusters, all that was needed for their resolution being additional telescopic power. This, however, has been found to be a mistake, and we are indebted to the new science of Spectrum Analysis for the discovery.

84. It has already been explained that the light of the sun and the fixed stars (which are in reality distant suns), when analysed, gives a spectrum, having black lines on a coloured ground; and that the light of incandescent gas, gives a spectrum of coloured lines upon a black ground.

85. On applying this test to the light of the nebulæ, it has been found that all those nebulæ which could be resolved into separate stars, have a spectrum with dark lines on a coloured ground, the same as that of the sun; but that some of the nebulæ which could not be resolved, have spectra with coloured lines on a black ground; proving that their light is produced by incandescent gas, chiefly hydrogen and nitrogen, and that no amount of telescopic power could show them to be composed of stars.

86. The forms presented by these nebulæ are extremely varied, as shown in the specimens exhibited on the Chart No. 52 to 66, which, in order to be understood must be seen, because they cannot be described. Many of course are simply globular in shape, more or less regular and defined, and are not represented in this Chart. Many are oblate or ring-shaped

but many also appear so peculiar and capricous in form, that it is difficult to understand how they could have been produced by the operation of natural laws.

87. There is, however, much that is still mysterious and unknown connected with these celestial objects, and the more that they are examined, the more wonderful do they appear. Perhaps the most remarkable circumstance connected with them is, that they undergo sudden and important changes, which of all things we should have least expected. This, however, may yet become a clue to the discovery of their real nature. It may be added, that although astronomers have, for a long time adopted Sir William Herschel's suggestion, that these nebulæ are Galaxies like our own Milky Way, lying at enormous distances in the immensity of space. Mr Proctor has recently challenged this opinion, and given very good reasons for believing that for the most part they belong to the Milky Way itself. It is not impossible, however, that in part, both doctrines may be true, and that while the greater number of the nebulæ may be connected with our own Galaxy, some at least may be altogether independent systems.

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1877.

NOTE.

THE Chart, of which this is the accompanying Hand-Book, has two peculiarities.

First,—Being primarily an Educational Map, the chief purpose of which is to enable the student to recognise on the paper the constellations as they are usually seen in the heavens, all but the most prominent stars have been toned down, without altering their magnitudes. By this means the eye is not confused with multitudes of stars which are never seen except when the sky is very clear.

Second,—It is drawn upon GALL'S PROJECTION, which is better suited than any other for presenting a large portion of the heavens in one view. The formula of its construction is as follows:—'*The degrees of latitude are projected stereographically, and the longitude is rectified at the 45th parallels.*'—See 'Proceedings,' Royal Geographical Society, 1871, p. 159.

HAND-BOOK TO ASTRONOMY.

SHEET No. 4.

CHAPTER I.

INTRODUCTORY OBSERVATIONS.

1. As the earth turns on its axis once every day, the heavens appear to be moving in the opposite direction; the axis on which they seem to revolve corresponding with the axis of the earth's rotation.

2. The whole heavens are sprinkled over with stars of different magnitudes without any regularity; but astronomers have grouped them into constellations bounded by imaginary lines; so that every star must belong to some particular constellation.

3. The stars lying near the plane of the earth's orbit are grouped into twelve constellations, called the signs of the Zodiac; and the sun appears to travel through these constellations once every year. The sun's path is called the Ecliptic.

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the twelve constellations called the signs of the Zodiac in the following order: Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricornus, Aquarius, and Pisces. They may be more easily remembered by the following lines giving the English names:

The RAM, the BULL, the heavenly TWINS,
And next the CRAB the LION shines,
The VIRGIN and the SCALES.
The SCORPION, ARCHER, and FISH-GOAT,
The MAN who pours the WATER out,
And FISH with glittering tails.

9. The position of any star reckoned *perpendicularly* is measured by the number of degrees distant from the north pole. This is called its 'north polar distance;' or it may be measured by the number of degrees distant (north or south) from the equator, and this is called its north or south declination. Its position *horizontally* is measured by its distance eastwards, in hours, minutes, and seconds, from the first point in Aries. Twenty-four hours complete the circuit.

CHAPTER II.

Movements of the Stars.

10. At night, when the sun sets, an entire half of the heavens becomes visible; but it depends on the latitude of the country how much more will be brought into view during the night by the revolving of the sphere.

11. At the poles there can be no change in this respect, because the stars above the equator never set, and those that are below never rise. In tropical countries, nearly the whole heavens are brought successively into view between sun-set and sun-rise. In temperate regions the polar heavens are always visible at night, extending to within as many degrees of the equator as is the latitude of the place. For example, to a country in 20 degrees latitude, there would be 20 degrees of the polar heavens that would never set, and 20 degrees round the opposite pole that would never rise.

12. There must always be a portion of the heavens in which the stars cannot be seen—that is the portion in which the sun happens to be at the time. But as he is always moving onwards in his path, the stars which are hidden by the glare of his light gradually come again into view.

13. There is thus a continual change in the celestial scenery, till the whole revolution has been completed once every year. For example, the constellations which at present are visible at midnight, will, one month hence, occupy the very same position at ten o'clock in the evening.

14. For the same reason, if we were to rise to-morrow morning at four o'clock, we should see the constellations in the position which they will occupy three months hence at ten o'clock. Each month in the year is equivalent to two hours in the day.

CHAPTER III.

The North Polar Heavens.

15. The most conspicuous group of stars in the northern sky is one called Charles' Wain, or the Plough, to which it bears a considerable resemblance.

It will be found in the map of the North Polar heavens, on the lower side, in the centre.

16. The Plough forms part of the constellation 'Ursa major' ('the Great Bear'); and as its two foremost stars point upwards to the pole star, around which all the others revolve, it is the most convenient guide, not only to that star, but by its means, to all the other constellations in the northern heavens.

17. As the Plough travels round the pole star once every day, we must not expect to see it always in the same position. It is only in the *autumn* evenings that we find it as we have represented it; and then it is to be seen between the pole star and the northern horizon.

18. In *winter* it is seen to the east of the pole star, travelling upwards with its handle pointing downwards. In *spring* it is almost directly over our heads; and in *summer* it is seen to the west of the pole star, travelling downwards, with its handle pointing upwards.

20. The pole star is a conspicuous star of the constellation

Ursa minor, situated near that point round which the heavens appear to revolve; and is important, because it guides us to all the other constellations of the northern heavens. If we stand with our back to the south and look up, it will be seen nearly in a line with the two front stars of the Plough, which on that account are called 'the pointers.'

21. On the other side of the heavens, and at about an equal distance from the pole star, is another beautiful constellation called Cassiopeia (sometimes written Cassiopea). Its five most conspicuous stars form the letter W, one of its halves being flattened.

In autumn it is directly over our heads, in winter it is west of the pole star, in spring it is under the pole star, and in summer it is in the north-east.

22. These two groups of stars, the Plough and Cassiopeia, enable us to divide the heavens into two *halves;* but, for our greater convenience, we require a division into *quarters.* This is obtained by two resplendent stars, one on each side, between the Plough and Cassiopeia. These are Capella and Vega; the one being situated in the constellation Auriga (the Charioteer), the other in the constellation Lyra (the Lyre). Although Capella and Vega are, both of them, single stars, Capella may be easily distinguished by its having a companion star a little farther down towards the left. Their positions also may be remembered by keeping in mind that Capella, the little goat, is running away from the Great Bear.

23. These four, the Plough and Cassiopeia, Capella and Vega, supply us with guides to the four quarters of the northern heavens, and form an ellipse, with the pole star in the centre, thus—

24. The constellation of which the pole star forms a part is called Ursa minor (the Lesser Bear), the tail of which is long and turned upwards, thus—

25. The constellation Draco (the Dragon), lies between the Plough and Vega. It has the appearance of a crooked serpent, with its tail between the two Bears, and its head bent downwards. Its head appears shaped like a diamond composed of four stars; but the star in front belongs to another constellation.

Polestar.

CHAPTER IV.

Cassiopeia Quarter.

Autumn Stars.

26. When we begin to study the constellations in the autumn we find Cassiopeia over our heads, the Plough low

down in the north, Capella in the north-east, and Vega in the north-west.

27. Beneath Cassiopeia towards the south, there is a range of five bright stars glittering in a curved line, thus—

28. The furthest star on the right hand belongs to the constellation Pegasus, the three in the middle belong to the constellation Andromeda, while the star on the left hand belongs to the constellation Perseus.

29. There are two bright stars below the two to the right, forming a great square, and other two beneath the three to the left, forming a large W, thus—

30. Three of the four stars forming the great square belong to the constellation Pegasus (the flying Horse), which is represented galloping with its head downward and its feet up.

The three stars form the flank of the horse. The head and neck are represented by an angle of stars to the right; while above that, the two fore legs are represented as spread out in two horizontal lines, thus—

31. The lowest star of the great W belongs to the constellation Aries (the Ram), which is the first sign of the Zodiac. The brightest stars of this constellation appear as in the following diagram:—

32. Between Aries and Pegasus there is an irregular line of faint stars, belonging to the constellation Pisces (the Fishes), which is the second sign of the Zodiac.

33. Underneath Aries and Pisces is a very brilliant constellation, called Cetus (the Whale), one of the stars of which (called Mira) is a variable star, changing in brightness from the second magnitude to the twelfth, and back again from the

twelfth to the second in 331 days. Mira is the third from the top.

Mira.

CHAPTER V.

Capella Quarter.

Winter Stars.

34. The constellations have now moved so far to the right, that new stars have come into view, belonging to the Capella Quarter, which now appears in the south.

35. Underneath Perseus, noticed in No. 28, and to the left of Aries, noticed in No. 31, we find the constellation Taurus (the Bull), which is represented pushing with its horns towards the left, its head bent downwards. The two horns are represented by two bright stars to the left, under Capella; its head in the centre is formed of a triangular cluster of stars, the

brightest of which (Aldebaran) is the Bull's eye. To the right, but higher, is another cluster, called the Pleiades.

36. Directly under Capella and the two horns of the bull is the constellation Orion, one of the most beautiful groups of stars in the heavens. The stars at the four corners represent the shoulders, the foot, and the knee of the hero. The three stars across the middle are his belt, and from the belt

hangs his sword, which is composed of a falling line of fine stars and nebulæ. Above the shoulders are three small stars on the cheek.

37. To the left of Orion there is a grand curve of bright stars, six in number, reaching down from Capella, at the top, to the brightest star in the whole heavens, Sirius the Dog Star. The highest is Capella, with its companion star. The next

two are Castor and Pollux of the constellation Gemini. Another star considerably further down is Procyon, the Little Dog, and lowest of all is Sirius.

CHAPTER VI.

Ursa Major Quarter.

Spring Stars.

38. Month after month the stars have been advancing westward, and now the Plough is overhead. To the left of Castor and Pollux is the constellation Cancer (the Crab), none of the stars of which are prominent. To the left of this, however, is the constellation Leo (the Lion).

39. The six stars on the right have the appearance of a reaping-hook, the lowest star of which is Regulus, a very bright star. The loins are represented by two stars, and the tail by one.

40. To the left of Leo, but considerably further down, is

another fine constellation called Virgo (the Virgin), the chief stars of which appear to be arranged in the form of the letter y. The brightest star in this constellation is the lowest, which is called Spica, an ear of corn, which she holds in her hand.

41. Beneath Virgo are four bright stars belonging to the constellation Corvus (the Crow).

42. We must now direct our attention again to the Plough, the handle of which points to a large and beautiful triangle,

with a bright star in the centre. This central star, and the two to the right, belong to the constellation Boötes.

43. The star to the left belongs to the constellation Corona Borealis (the Northern Crown), and forms the brightest star of a semicircle representing the crown.

CHAPTER VII.

Vega Quarter.

Summer Stars.

44. The star Vega is now in the ascendant, and the constellations which last quarter were in the west are now in the south. To the left of Corona Borealis is a magnificent constellation called Hercules, presenting the appearance of a gigantic lily opening its cup towards Vega. The stalk of the lily ex-

tends downwards into another small constellation called Serpens,

in which the stalk appears broken. Three bright stars form the broken part.

45. In a straight line from Vega downwards towards the left there are three bright stars belonging to the constellation Aquila (the Eagle). Being in a straight line they point upwards to Vega.

46. To the left of Aquila, but higher, is a curious cluster

of stars called the Dolphin, in the form of a boy's kite. It is a small cluster, and although none of the stars are bright, it attracts notice.

47. Above the Dolphin, and to the left of Vega is the constellation Cygnus (the Swan). It has the appearance of two half wheels, or bow-windows, overlapping one another.

48. To the left of Cygnus and the Dolphin, is the constellation Pegasus, belonging to the Cassiopeia quarter, from which we set out. See No. 30.

49. Having travelled round the heavens, guided by the constellations Ursa major and Cassiopeida, and by the stars Vega and Capella, the student will be able to study all the others with the help of the maps on the accompanying sheet.

50. All the stars which can be seen by the naked eye will be found in these maps—that is to say, all the stars from the first to the sixth magnitudes. The stars of the first magnitude are largest, and are distinguished by having eight rays, the second have seven, the third six, the fourth five, the fifth four, while the stars of the sixth magnitude, which are the smallest that can be seen with the naked eye, are represented simply as points.

51. As only the larger stars are distinctly seen, except upon clear nights, the smaller stars have been dimmed upon the maps, so as to present more distinctly the actual appearance which the constellations have in the heavens.

52. The Milky Way may be traced round the whole heavens as an irregular nebulous band of faint light, which appears in all the maps. There are also nebulæ which are small patches of faint light, and are distinguished by having no rays. These have been described in connection with sheet No. 3.

53. The ancient astronomers gave names to individual stars; and as that is the most convenient method of distinguishing them for popular use, these names have been appended. But modern astronomers have found it necessary to adopt a more systematic plan. The stars being divided into constellations, the Greek alphabet is first used, beginning with the largest star in each. When the Greek alphabet is exhausted, the Roman letters are next employed; and when

these fail, numbers are attached, and can be used to any extent.

54. The following is a translation of the Latin and Greek words used in naming the constellations when they are not proper names :—

Antlia, *the pump.*
Aquarius, *the water-bearer.*
Aquila, *the eagle.*
Ara, *the altar.*
Aries, *the ram.*
Aurigo, *the charioteer.*
Australis, *south.*
Borealis, *north.*
Cancer, *the crab.*
Canis, *dog.*
Canes, *dogs.*
Capella, *the little goat.*
Cælum, *a graving tool.*
Cetus, *the whale.*
Columba, *the pigeon.*
Coma, *the hair.*
Corvus, *the crow.*
Corona, *the crown.*
Crater, *the cup.*
Crux, *the cross.*
Cygnus, *the swan.*
Delphinus, *the dolphin.*
Draco, *the dragon.*
Equuleus, *the little horse.*
Fornax, *the furnace.*
Gemini, *the twins.*
Grus, *the crane.*
Horologium, *the clock.*
Hydrus, *the water snake.*
Indus, *the Indian.*
Lacerta, *the lizard.*
Leo, *the lion.*
Lepus, *the hare.*
Libra, *the scales.*
Lupus, *the wolf.*
Lyra, *the lyre.*
Major, *the greater.*
Minor, *the less.*
Monoceros, *the unicorn.*
Musca, *the fly.*
Norma, *the rule.*
Octans, *the octant.*
Ophiuchus, *the serpent holder.*
Pavo, *the peacock.*
Pictoris, *belonging to a painter.*
Piscis, *the fish.*
Pisces, *the fishes.*
Reticulum, *the little net.*
Sagitta, *the arrow.*
Sagittarius, *the archer.*
Scalptoris, *belonging to an engraver.*
Sculptoris, *belonging to a sculptor.*
Scutum, *the shield.*
Sextans, *the sextant.*
Taurus, *the bull.*
Ursa, *the bear.*
Venatici, *used for hunting.*
Virgo, *the virgin.*
Volans, *flying.*
Vulpecula, *the little fox.*

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